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[TITLE OF THE INVENTION]

TROIDAL TYPE CONTINUOUSLY VARIABLE TRANSMISSION DISK

[ABSTRACT OF THE DISCLOSURE]

[OBJECT] It is an object of the invention to provide a troidal type continuously variable transmission disk which not only permits the production cost thereof but also can extend the life thereof.

[STRUCTURE] The disk 1 includes a traction surface 4 having a concavo-arc-shaped cross section which is interposed between a small diameter end portion 2 and a large diameter end portion 3. In the central portion of the end face of the disk on the small diameter end portion 2 side, there is formed a through hole which extends through the disk up to the large diameter end portion 3 side end face of the disk, while the inner peripheral surface of the through hole is used as an inside diameter surface 5 of the disk 1. Here, when, among metal flows 6 existing in the disk 1, a metal flow 6, which has such a positional relationship with respect to the surface of the disk that an angle θ formed between a metal flow on the traction surface 4 side and the tangent of the traction surface 4 is smaller than or equal to 30°, is defined as a "metal flow 6 along the disk surface", the disk 1 is structured such that the "metal flow 6 along the disk surface" exists at least in the traction surface 4.

WHAT IS CLAIMED IS:

1. For use in a troidal type continuously variable transmission comprising input and output disks each including a traction surface of a concavo-arc-shaped cross section interposed between a small diameter end portion and a large diameter end portion and disposed concentrically with each other with their respective traction surfaces opposed to each other, and a power roller fictionally engageable with the respective traction surfaces of the input and output disks to thereby transmit power, a disk including metal flows, wherein, when, among said metal flows, a metal flow, which has such a positional relationship with respect to the surface of said disk that an angle θ formed between a metal flow on said traction surface side and the tangent of said traction surface is smaller than or equal to 30°, is defined as a metal flow along said disk surface, said disk is structured such that said metal flow along said disk surface exists at least in said traction surface.

BACKGROUND OF THE INVENTION

[0001]

1. Field of the Invention

The present invention relates to a disk for use in a troidal type continuously variable transmission which can be used in vehicles, various kinds of industrial machines, and the like.

[0002]

2. Description of the Related Prior Art

A troidal type continuously variable transmission comprises, for example, as shown in Fig. 15, input and output disks a and b which are disposed concentrically with each other, and a power roller c which is interposed between the respective traction surfaces f and i of the input and output disks a and b.

[0003]

In the input disk a, between the small diameter end portion d and large diameter portion e thereof, there is formed a traction surface f the cross section of which provides a concavo- arc shape and, in the output disk b, similarly, between the small diameter end portion g and large diameter portion h thereof, there is formed a traction surface i the cross section of which provides a concavo-arc shape. On the side of the input disk a that is distant from the power roller c, there is concentrically disposed a loading cam through a plurality of engaging rollers (both of them are not shown), so that, due to the oil pressure that is supplied between the loading cam and input disk a, a driving force proportional to a torque can be applied toward the input disk a.

[0004]

The power roller c is a device which can be fictionally engaged with the respective traction surfaces f and i of the input output disks a and b to thereby transmit power; and, the power roller c is supported by a threonine j in such a manner that it can be inclined in the diameter direction of the input output disks and b. And, if the threonine j is operated by a drive mechanism (not shown) to thereby change the contact positions of the power roller c in the diameter direction thereof with respect to the input and output disks a and b, then a rotation speed ratio between the input and output disks a and b, that is, a speed change ratio can be varied continuously.

[0005]

By the way, the troidal type continuously variable transmission is required to transmit a higher torque and, for this reason, the input and output disks a, b and power roller c receive very large repeated bending stress and repeated shearing stress when compared with ordinary mechanical parts (such as ordinary gears and bearings); and, in the input and output disks a and b, especially, as shown by fine hatchings in Fig. 17, the traction surfaces f, i, small diameter end portions d, g, and

small diameter end portion side d (g) inside diameter surfaces receive large repeated bending stress and repeated shearing stress. Therefore, when manufacturing the input and output disks a and b, it is necessary to use such highly durable material that can resist such repeated bending stress and repeated shearing stress.

[0006]

Conventionally, to manufacture the input and output disks a and b, for example, as shown in Fig. 12, cylindrical-shaped blank material (carburizing steel or the like) having a length equal to the axial length of the input and output disks a and b is shaved or cut to thereby produce such a final shape as shown in Fig. 16.

[0007]

[Problems to be Solved by the Invention]

However, in the conventional method for manufacturing the input and output disks a and b, the yield of the material is poor and it takes long time to cut or shave the material, with the result that the production costs of the input and output disks a and b are soaring.

[0008]

Also, because a metal flow (the flow of structure) k is arranged along the axial direction of the disk, in the traction surfaces f and i with which the power roller c is fictionally engaged with a large pressure, the metal flow k comes to an end and, actually, does not extend along the traction surfaces f and i. As a result of this, not only the material is easy to peel off in the portions of the traction surfaces f and i with which the power roller c is fictionally engaged, but also an impact crack or a fatigue crack is easy to occur in the input and output disks a and b starting at the broken portions of the metal flow k, thereby providing an obstacle to the long lives of the input and output disks a and b.

[0009]

SUMMARY OF THE INVENTION

The present invention aims at eliminating the drawbacks found in the disks used in the conventional troidal type continuously variable transmission. Accordingly, it is an object of the invention to provide a disk for use in a troidal type continuously variable transmission which not only can reduce the production cost thereof but also can realize a long life.

[0010]

By the way, in the center of the cylindrical-shaped blank material and in the neighboring portion of such center (that is, in Figs. 12 and 16, 0.3 D portions: where, D designates the diameter of the cylindrical-shaped blank material), nonmetal interpositions, which have a great influence on the fatigue breaking strength of the disk, are high in density (see Fig. 13) and, therefore, it is desired that the nonmetal interpositions are not present in the heavy bending stress areas of the disk (for example, the inside diameter surface of the small diameter end portions and the like) and in the areas of the traction surfaces that receive the heaviest shearing stress.

[0011]

Referring now to the nonmetal interpositions, it is known that the strength of material with respect to repeated bending stress is greatly influenced by the size of the defective portion thereof at which the breaking of the material can start. For example, in a book titled "Influence by minute defects and interpositions" (Written by Mr. Murakami, published by Yoken Do Co.), there is stated as follows: that is,

The fatigue limit of material when repeated bending is applied to the material can be expressed by the following equation;

$$\sigma_w = \frac{K\,(Hv+120)}{((area)^{1/2})^{1/6}} \quad \cdots (1)$$

where K: 1.43 (when a defect is present on the surface of the material);

K: 1.41 (when a defect is present in such a manner as to be in contact of the material surface)

K: 1.56 (when a defect is present in the interior of the material)

σ_w : fatigue limit

Hv: hardness of material (relating to the strength of the matrix of the blank material), and,

$(area)^{1/2}$: a square root of a projection area obtained when a defect or a crack is projected in the greatest main stress direction (an amount representing the dimension of a defect or a crack).

[0012]

Therefore, for a mechanical part which is used under severe conditions such as the troidal type continuously variable transmission (that is, under such severe conditions, the mechanical part receives not only great repeated bending stress but also great repeated shearing stress), it is desirable to use material in which a defect providing a starting point of the breaking of the material has been controlled.

[0013]

Generally, it is known that the main defect cause of steel requiring high strength is an oxide-related interposition. As a method for controlling such oxide-related interposition, there are known the JIS method (JIS-G-0555), the ASTM method (ASTM-E45) and the like. Also, for bearing material requiring especially high cleanliness, there are known a method which, for example, as disclosed in Japanese Patent Publication No. 3-294435 of Heisei, melts material again using an electron beam melting method to float large-sized oxide-related interpositions of the material to thereby control the cleanliness of the material, and an extreme statistical method disclosed in the above-cit d book "Influence by minute defects and interpositions" (Written by Mr. Murakami, published by Yoken Do Co.) (that is, a method in which the greatest oxide-related interposition diameter per

unit area S_0 is investigated from several test pieces and, after then, the thus investigated result is processed statistically, thereby predicting the greatest oxide-related interposition diameter in an area S required).

[0014]

For a ball-and-roller bearing, a gear and the like, using the above-mentioned cleanliness controlling methods, the steel cleanliness is controlled so that they are able to perform their expected functions. However, in the disks and power roller which constitute the troidal type continuously variable transmission, the absolute values of the stress applied thereto (in particular, the contact surface pressure thereof is of the order of 4.0 GPa and the bending stress thereof is 90 kgf/mm_2) are large when compared with the ball-and-roller bearing, a gear and the like to which normal repeated stress is applied. Besides, not only the repeated bending stress and repeated shearing stress are applied simultaneously to the disks and power roller but also the volume thereof receiving such stress is large. For these reasons, in the troidal type continuously variable transmission, it is difficult to obtain sufficient strength using the above-mentioned interposition control method. That is, there is desired new means which can cope with the influence of the interpositions.

[0015]

[Means for Solving the Problems]

In attaining the above object, according to the invention, there is provided a disk for use in a troidal type continuously variable transmission comprising input and output disks each including a traction surface of a concavo-arc-shaped cross section interposed between a small diameter end portion and a large diameter end portion and disposed concentrically with each other with their respective traction surfaces opposed to each other, and a power roller fictionally engageable with the respective traction surfaces of the input and output disks to thereby transmit power,

wherein the disk includes metal flows and also wherein, in the finished state of the disk after all necessary finishing operations are executed, when, among the metal flows of the disk, a metal flow, which has such a positional relationship with respect to the surface of the disk that an angle θ formed between a metal flow on the traction surface side and the tangent of the traction surface is smaller than or equal to 30°, preferably, smaller than or equal to 20°, is defined as a metal flow along said disk surface, the disk is structured such that such metal flow along the disk surface exists at least in the traction surface thereof.

[0016]

Here, when the angle θ of a metal flow with respect to the tangent of the traction surface exceeds 30°, then the metal flow becomes equivalent to an end flow (that is, a metal flow which does not exist along the disk surface), which not only causes the material to peel off but also incurs the bending fatigue thereof or the like to thereby cause the disk to break (that is, the crack life of the disk is shortened).

[0017]

Also, although it is desirable that the lower limit value of the angle θ may be infinitely approximate to 0°, $\theta \fallingdotseq 0°$, as can be seen from the relationship between a state of the blank material after forged (shown by a two-dot chained line) and a state of the blank material after completion of working (shown by a solid line) in Figs. 5 and 9, for example, in the case of the traction surface 4 and inside diameter surface 2, the margin between them varies, with the result that the angles of metal flows 6 intersecting with the traction surface 4 and inside diameter 2 after worked vary from the angles thereof after forged. For example, if a special attention is paid to one metal flow 6 after forged, then it is clear that it does not intersect with above-mentioned respective surfaces at a constant angle in their respective depth directions (which correspond to the margin amounts thereof) but the intersecting angles of th pr s nt metal flow

6 vary moment by moment. And, the intersecting angle θ of the metal flow with respect to the respective surfaces used in the present application, that is, the angle θ of the metal flow having an influence on the peel-off and bending fatigue of the material is defined that it does not mean the state of the blank material after forged but means the state of the blank material after worked, namely, the practically usable state of the material.

[0018]

Therefore, it may be sufficient that the metal flow 6 after forged shows a state which, when the working is completed, is believed to be able to provide the range of the angle θ defined in the present application by means of a given margin. However, although a product having the angle θ equal to 0° or infinitely approximate to 0° is the most desirable from the viewpoint of the performance of the disk, it is also desirable to reduce the margin as much as possible. Also, in order to avoid the variations in the margin, or in order to remove the margin at right angles or at other angles with respect to the surfaces, that is, due to the working need, if the angle θ is obtained extremely severely, then poor working or similar inconveniences can occur, that is, the yield of the products can be degraded, with the result that the manufacturing cost of the disk is caused to rise.

[0019]

Since the present invention has an object to provide a disk which not only can improve the performance thereof but also can reduce the manufacturing cost thereof and a method for manufacturing the same disk, there is employed $\theta = 2 - 30°$, preferably, $\theta = 5 - 20°$. In particular, the lower limit of the angle θ is defined mainly from the viewpoint of the improvement in both of the performance and yield, whereas the lower limit thereof is defined, as described above, mainly from the viewpoint of the improvements in the peel-off and bending fatigue.

[0020]

The foregoing description is the definition of the metal

flow existing along the disk surface.

("i") Also, the "metal flow along the disk surface", preferably, may exist not only on the above-mentioned traction surface but also on the portion of the inside diameter surface of the disk that extends axially from the small diameter end face of the disk at least in the range of 1/3A where the length of the disk in the axial direction thereof is expressed as A.

[0021]

In this manner, the "metal flow along the disk surface" is formed in such a manner as to exist also on the inside diameter surface of the disk axially from the small diameter end face of the disk at least in the range of 1/3A. The reason for this is as follows: that is, since a peripheral groove for a stop ring as shown in Fig. 17 and the like are formed in the inside diameter surface, the inside diameter surface is a portion which can be affected severely by the bending stress or the like; and, therefore, up to the area of 1/3A of the disk, it is necessary to dispose the metal flow along the disk surface in the range of θ angle according to the invention.

("ro") In this case, if the "metal flow existing along the disk surface" is formed in such a manner as to exist also in the end face of the disk on the small diameter end portion side thereof, then the bending fatigue and the concentration of the stress applied to the peripheral groove can be relieved, thereby being able to extend the life of the disk still further.

("ha") Further, referring to Fig. 14, preferably, the "metal flow existing along the disk surface" may exist along the traction surface in the peripheral direction thereof in the range of an angle α of 45° or more, preferably, 48° or more, where the angle α is an angle which is formed by the traction surface with respect to a horizontal line (a line extending in parallel to the axis of the disk) passing through the center of radius O.

[0022]

In this case, the area that receives the severest bending stress and the like in the traction surface (see the fine hatching portions shown in Fig. 17) can be covered by the "metal flow existing along the disk surface", which makes it possible to prevent the breakage of the disk caused by the bending stress and the like.

("ni") Further, the troidal type continuously variable transmission disk according to the invention is manufactured by forging (which will be described later) using a mold. In this case, referring to Figs. 10 and 15, where the minor radius of a contact ellipse between the traction surface and power roller is expressed as b when the power roller is set horizontal (that is, parallel to the axis of the disk), that is, when a speed change ratio is 1:1, preferably, a nonmetal interposition having a high density may exist in an area which is distant by 1.5b or longer in the depth direction from the traction surface.

[0023]

The reason for the above is as follows: that is, the area that receives the severest shearing stress in the traction surface is an area which exits within 1.5b in the depth direction from the traction surface and, therefore, if no interposition is present in this area, then the life of the disk cannot be influenced at all (see Fig. 11).

("ho") Also, as described above, since the portion of the inside diameter surface that extends axially in the range of 1/3A from the small diameter end portion side end face is a portion which can be affected severely by the bending stress or the like due to the formation of the peripheral groove for the stop ring and the like, preferably, no interposition may be present in the present inside diameter surface 1/3A range portion.

[0024]

By the way, Figs. 18 and 19 respectively show methods

respectively for manufacturing a troidal type continuously variable transmission disk, which are disclosed in Japanese Patent Publication No. 9-126289 of Heisei. These disk manufacturing methods can be used to manufacture only the disk that includes a metal flow of $\theta = 0°$ among the disks according to the present invention, but they are not able to manufacture the remaining disks including metal flows of other angles than$\theta = 0°$. In brief, in the above-disclosed manufacturing methods, there are found some problems to be solved.

[0025]

In particular, referring at first to the conventional disk manufacturing method shown in Fig. 18, cylindrical-shaped blank material (carburizing steel or the like) n with its metal flows m extending on the outer peripheral surface of the blank material along the axial direction thereof is concentrically held by and between an upper mold o and a lower mold p, and the blank material n is then molded by a given among (see Fig. 18 (b)). Here, the upper mold o includes a small diameter end portion molding surface s for molding the small diameter end portion r of a disk q and a traction surface molding surface u for molding the traction surface t having a concavo-arc-shaped cross section of the disk q, whereas the lower mold p includes a large diameter end portion molding surface w for molding the large diameter end portion v of the disk q. And, the upper mold o and lower mold p are moved further closely to each other to thereby pressure forge the blank material n in the axial direction thereof several times, so that not only the small diameter end portion r and large diameter end portion v are respectively molded in the upper and lower end portions of the blank material n respectively, but also the traction surface t is molded between the small diameter end portion r and large diameter end portion v.

[0026]

Next, as shown in Fig. 18 (c), the upper mold o and lower mold p are moved most clos ly to each other to thereby pressure

forge the blank material n into the final shape of the disk q and, after then, not only the thus forged and molded final shape is ground or finished but also the inside diameter surface portion thereof is cut to thereby produce the inside diameter surface x of the disk q1, thereby completing the final product of the disk q1 that is shown in Fig. 18 (d).

[0027]

However, in the present conventional manufacturing method, since the cylindrical-shaped blank material n is forged up to the final shape of the disk q1 using one kind of upper and lower molds o and p, the contact time between the upper and lower molds o, p and the blank material n is long, which makes it easy for the upper and lower molds o and p to be influenced by heat which is generated in the molding or forging operation. As a result of this, there is raised an inconvenience that the surface hardness of the upper and lower molds o and p can be lowered and the lives of the upper and lower molds o and p can be thereby shortened.

[0028]

Also, in the final stage of the above molding operation, because the space between the upper and lower molds o and p is filled with the blank material n in a tightly closed state, the thicknesses of the corner portions of the upper and lower molds o and p can be easily reduced or burrs are easy to occur in the present corner portions. Besides, if trying to improve the shape of disk q1 by force, then an excessive molding load must be applied to the upper and lower molds o and p, with the result that the upper and lower molds o and p can be broken.

[0029]

Further, in the step to be executed after the blank material is mold forged, the forged blank material is finished by grinding. Therefore, the grinding margin must be minimized in order to shorten the working time necessary for the grinding operation as much as possible. As a result of this, it is necessary to reduce the degree of abrasion in the upper and lower molds o

and p during the forging operation, so that the lives of the upper and lower molds o and p can be inconveniently shortened.

[0030]

In addition, since the upper and lower molds o and p are not structured such that they hold the cylindrical-shaped blank material n within their interior portions, the cylindrical-shaped blank material n is easy to shift from the centers of the upper and lower molds o and p, which results in the worsened working precision.

[0031]

Thus, in order to eliminate the above-mentioned inconveniences found in the conventional disk manufacturing method, the present inventors have developed a conventionally unknown new disk manufacturing method as follows: that is, this disk manufacturing method is suitable for manufacturing a disk according to the invention and, especially, in addition to the disk according to the invention, the present method is ideal for manufacturing a disk which includes the before-mentioned respective means ("i") and ("ha").

[0032]

In particular, the present disk manufacturing method comprises:

a first step in which cylindrical-shaped blank material with its metal flows existing on the outer peripheral surface thereof and extending along the axial direction of the blank material is swaged using a first forging mold;

a second step in which the swaged blank material is molded using a second forging mold to thereby form a portion of the inside diameter surface of the disk in the central portion of the upper end face of the blank material, and the shape of the molding surface of the second forging mold is transferred to the present inside diameter surface portion; and,

a third step in which the blank material obtained in the second st p is molded using a third forging mold to thereby

form a small diameter end portion, a traction surface and a large diameter end portion, the inside diameter surface portion molded in the second step is pushed further to such an extent as allows a residual wall to be left between the back surface of the large diameter end portion and the present inside diameter surface portion, and further a burr is formed on the outside diameter surface of the present large diameter end portion,

wherein, after the burr and residual wall of the mold forged product obtained through the respective steps are removed, the mold forged product is ground to thereby form a disk having its final shape, and the thus ground disk is heat treated and is finished.

[0033]

In the present disk manufacturing method, since the mold forging operation is carried out in three steps using three kinds of molds, the contact time between the mold and blank material can be shortened, which makes it possible to reduce the heat influence on the molds during the molding operation. As a result of this, the mold surface hardness can be maintained in a good level to thereby be able to improve the lives of the molds used.

[0034]

Also, if the amount of swaging of the cylindrical-shaped blank material is increased in the first step, then it is possible to reduce the molding amounts not only in the second step but also in the third step in which a high molding load is required in order to obtain a shape approximate to the final shape of the product. As a result of this, the working burden of the forging mold in the second and third steps can be relieved so that the lives of the molds can be extended.

[0035]

Further, the increased swaging amount of the cylindrical-shaped blank mat rial in th first step can reduce not only the degree of push-in of the inside diameter surface portion of the forging mold in the second step but also the degree

of further push-in of the forging mold inside diameter portion molded in the second step. This makes it possible to enhance greatly the life of the portion of the material of the forging mold that can be most influenced by heat.

[0036]

Still further, since the mold forging operation is carried out in three steps using three kinds of molds, the flow of the material during the forging operation can be set freely. This means that a shape matched to the final shape of the product can be set in the previous steps (that is, in the first and second steps), thereby being able to provide a well-balanced mold forged product.

[0037]

Yet further, because the disk is obtained by grinding the mold forged product, even if the forged product before ground is a rough forged product (for example, a hot-forged product), the present disk manufacturing method is sufficiently able to deal with such forged product; and, because there is little need to pay attention to the abrasion of the molds (that is, because, even if the molds wear to some degree, they can still be used), the costs of the molds can be reduced in the long run.

[0038]

In addition, due to the fact that, in the third step, the burr is produced on the outside diameter surface of the large diameter end portion at the time when the molding operation is completed, tightly closed forging is avoided to thereby be able to prevent an unnecessary molding load from increasing. This makes it possible to improve the lives of the molds.

[0039]

By the way, if the height H1 of the central portion of the blank material after it is swaged in the first step is set in the range of 80 - 120% of the height 2 of the blank material when the forged product is completed in the third step, then the enhanced lives of the molds in the second and third steps

can be achieved effectively.

[0040]

Also, in the above-mentioned first to third steps, by disposing positioning means which is capable of centering or positioning the respective forging molds with respect to the blank material, the blank material can be positioned accurately and positively in the molding center of the forging molds in each step. Thanks to this, the blank material can be always molded at the correct position to thereby be able to provide a high-precision mold forged product. That is, there can be provided a forged product in which a metal flow existing along the surface of the disk according to the present invention can be obtained by a post-machining operation.

[0041]

Next, description will be given below of the conventional disk manufacturing method which is shown in Fig. 19. This is a method in which part of the inside diameter surface x of a disk q2 is molded when the blank material is forged by molds. That is, at first, as shown in Fig. 19 (b), the upper end portion of the cylindrical-shaped blank material n is drawn to thereby set the diameter of the present upper end portion smaller than the diameter of the small diameter end portion r and, next, the cylindrical-shaped blank material n is concentrically held by and between an upper mold y and a lower mold z and is then molded by a given amount (see Fig. 19 (c)). The upper mold y includes a small diameter end portion molding surface s for molding the small diameter end portion r of the disk q2, a traction surface molding surface u for molding a traction surface t having a concavo-arc shaped cross section, and a projection a1 which is provided in the central portion of the small diameter end portion molding surface s for molding a portion of the inside diameter surface x of the disk q2 from the small diameter end portion r side. On the other hand, the lower mold z includes a large diameter end portion molding surface w for molding the large

diameter end portion v, and a projection a2 which is provided in the central portion of the large diameter end portion molding surface w for molding a portion of the inside diameter surface x of the disk q2 from the large diameter end portion v side.

[0042]

Next, the upper and lower molds y and z are moved to approach each other further and the blank material n is forged several times in the axial direction thereof, whereby not only the small diameter end portion r and large diameter end portion v are molded respectively in the upper and lower end portions of the blank material n but also the traction surface t is molded between the small diameter end portion r and large diameter end portion v; and, then an operation to mold the inside diameter surface x by the projections a1 and a2 is started.

[0043]

Next, as shown in Fig. 19 (d), the upper and lower molds y and z are moved further to approach each other most closely and the blank material n is mold forged into the final shape of the disk q2. In this forging operation, the inside diameter surface x is held in a state where the residual wall a3 thereof is still left. After then, the residual wall a3 of the inside diameter surface x is removed by cutting or by grinding to thereby complete the inside diameter surface x and, at the same time, the blank material n is further ground, which completes the final product of the disk q2.

[0044]

In the above-mentioned convention disk manufacturing method, there occurs a phenomenon in which the end points of the metal flows m appearing in the upper and lower ends of the cylindrical-shaped blank material n in Fig. 19 (b) are pulled into the interior of the cylindrical-shaped blank material n in Fig. 19 (c); and, as a result of this, the metal flows exist along the surface shape of the disk q2 ($\theta = 0°$) ranging from the traction surface t to the small diameter end portion r and

the portion of the inside diameter surface x that is located on the small diameter end portion r side thereof.

[0045]

However, in the step shown in Fig. 19 (c), it is very difficult to mold the cylindrical-shaped blank material n in such a manner that the end points of the metal flows m are pulled into the interior of the cylindrical-shaped blank material n and, therefore, in most cases, the end points of the metal flows m are left somewhere on the upper and lower end faces of the blank material n. As a result of this, it is difficult to allow the metal flows having the angle of $\theta = 0°$ to exist positively along the surface of the disk q2.

[0046]

Also, there is a high possibility that a high-density nonmetal interposition existing in the neighboring portion of the central portion of the cylindrical-shaped blank material n can be left in the portion to which the bending stress is applied severely, that is, a portion ranging from the small diameter end face of the disk q2 axially to the portion of the inside diameter surface that extends in the 1/3A range thereof, which has an ill effect on the life of the disk.

[0047]

Thus, in order to eliminate the inconveniences found in the above-mentioned conventional disk manufacturing method, the present inventors have developed a conventionally unknown new disk manufacturing method as follows: that is, this disk manufacturing method is suitable for manufacturing a disk according to the invention and, especially, in addition to the disk according to the invention, the present method is ideal for manufacturing a disk which includes all of the before-mentioned means ("i") to ("ho").

[0048]

In particular, the present disk manufacturing method comprises: a first step in which a cylindrical-shaped blank

material with metal flows existing on the outer peripheral surface thereof and extending along the axial direction thereof is swaged using a first forging mold and, at the same time, the upper end portion of the present cylindrical-shaped blank material is drawn; and, a second step in which the blank material obtained in the first step is molded using a second forging mold to thereby form a traction surface and a large diameter end portion and, at the same time, a portion of an inside diameter surface is formed in the central portion of the present blank material in such a manner that a residual wall is left between the back surface of the large diameter end portion and the present inside diameter surface portion. And, the present disk manufacturing method is characterized in that, when forming a portion of the inside diameter portion in the central portion of the blank material in the second step, the upper end portion of the present blank material is restricted by a portion of the second forging mold to thereby prevent the present upper end portion from increasing in diameter during the molding operation and, at the same time, a high-density nonmetal interposition existing in the central portion of the present blank material is pushed into the lower end side of the blank material to thereby expand the lower end side of the blank material outwardly in the diameter direction thereof; and, further, after the residual wall of the mold forged product obtained through the respective steps is removed, the blank material is ground to thereby mold the same into the final shape of the disk and the thus molded disk is heat treated and finished.

[0049]

In the present disk manufacturing method, it is possible to obtain a disk (a finished product) simply and positively in which the "metal flows existing along the disk surface" each having the angle of $\theta = 2 - 30°$ exist respectively in the end face of the disk on the small diameter end portion side thereof, the traction surface of the disk, the outer peripheral surface

of the large diameter end portion of the disk, and the back surface of the large diameter end portion thereof.

[0050]

Also, partly because use of the mold forging operation makes it possible to reduce the diameter of the cylindrical-shaped blank material, partly because, in the second step, the upper end portion of the present blank material is restricted by a portion of the second forging mold to thereby prevent the present upper end portion from increasing in diameter during the molding operation, and partly because the high-density nonmetal interposition existing in the central portion of the present blank material is pushed into the lower end side of the blank material to thereby expand the lower end side of the blank material outwardly in the diameter direction thereof, there can be obtained simply and positively a disk in which the high-density nonmetal interposition does not exist in the following areas: that is, the area of the traction surface portion that receives the severest shearing stress in the traction surface portion, that is, the area extending in the depth direction from the traction surface by a distance less than 1.5 b; and, the area of the disk ranging axially from the end face of the small-diameter-end-portion side inside diameter surface portion receiving a severe bending stress due to formation of the peripheral groove for the stop ring up to the 1/3A (A is the axial length of the disk) range portion.

[0051]

By the way, preferably, in the second step, a burr may be produced on the outside diameter surface of the large diameter end portion at the time when the molding is completed. That is, the thus produced burr can avoid a tightly closed forging operation to th reby prevent an unnecessary molding load from increasing, which in turn makes it possible to enhance the lives of the molds.

[0052]

Also, in the above-mentioned first and second steps,

by disposing positioning means which is capable of centering or positioning the respective forging molds with respect to the blank material, the blank material can be positioned accurately and positively in the molding center of the forging molds in each step. Thanks to this, the blank material can be always molded at the correct position to thereby be able to provide a high-precision mold forged product.

[0053]

[DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION]

Now, description will be given below of the preferred embodiments of a troidal type continuously variable transmission according to the invention with reference to the accompanying drawings. In particular, Fig. 1 is an explanatory view of the input and output disks of a troidal type continuously variable transmission which are a first embodiment according to the invention; Fig. 2 is an explanatory view of a first step employed in a disk manufacturing method; Fig. 3 is an explanatory view of a second step employed in the disk manufacturing method; Fig. 4 is an explanatory view of a third step employed in the disk manufacturing method; Fig. 5 is an explanatory view of an example of a final step employed in the disk manufacturing method; Fig. 6 is an explanatory view of the input and output disks of a troidal type continuously variable transmission which are a second embodiment according to the invention; Fig. 7 is an explanatory view of a first step employed in a disk manufacturing method; Fig. 8 is an explanatory view of a second step employed in the disk manufacturing method; and, Fig. 9 is an explanatory view of an example of a final step employed in the disk manufacturing method.

[0054]

At first, description will be given below of a disk (a finished product) which is a first embodiment according to the inv ntion with reference to Fig. 1. This disk 1 includes a traction

surface 4 having a concavo-arc-shaped cross section interposed between a small diameter end portion 2 and a large diameter end portion 3; and, in the central portion of the end face of the disk 1 on the small diameter end portion 2 side thereof, there is formed a through hole which extends therethrough up to the back surface of the large diameter end portion 3, while the inner peripheral surface of the through hole provides an inside diameter surface 5. Here, with reference to Figs. 1 and 14, among the metal flows 6 that exist in the disk 1, a metal flow 6, which has such a positional relationship with respect to the surface of the disk 1 that the metal flow 6 on the traction surface 4 side has an angle θ of 2 - 30°, preferably, 5 - 20° with respect to a tangent P of the traction surface 4, is defined as a "metal flow 6 along the disk surface".

[0055]

In the disk 1, a "metal flow 6 along the disk surface" having the angle θ = 2 - 30° exists in the traction surface 4; a "metal flow 6 along the disk surface" having the angle θ = 2 - 30° exists in the area of the inside diameter surface 5 ranging from the end face of the inside diameter surface 5 on the small diameter end portion 2 side thereof to the range of 1/3A, where the length of the disk 1 in the axial direction thereof is expressed as A; and, a "metal flow 6 along the disk surface" having the angle θ = 2 - 30° exists in the outside diameter surface of the large diameter end portion 3 and in a portion of the back surface of the present large diameter end portion 3.

[0056]

Also, a "metal flow 6 along the disk surface" having the angle θ = 2 - 30° exists in the traction surface 4 in such a manner that, with reference to Fig. 14, it extends along the peripheral direction of the traction surface 4 in the range of an angle α of 45° with respect to a horizontal line passing through the center of curvature 0 of the traction surface 4 (that is, a line extending in parallel to the axis of the disk 1). By

the way, a metal flow 6 having the angle θ of greater than 30° with respect to the tangent P of the traction surface 4 becomes equivalent to an end flow (a metal flow which does not exist along the disk surface), so that such metal flow not only causes the material to peel off but also gives rise to the bending fatigue of the disk and thus the rupture of the disk (the lowered crack life).

[0057]

In the thus structured disk 1, since the "metal flow 6 along the disk surface" having the angle θ = 2 - 30° exists in the traction surface with which the power roller can be fictionally engaged with a large pressure, especially when the disk 1 is used under a low load condition, not only the material in the engaged portion of the traction surface 4 where it is fictionally engaged with the power roller can be prevented from peeling off, but also an impact crack or a fatigue crack is hard to occur in the disk 1 so that the long life of the disk 1 can be realized.

[0058]

Also, because the "metal flow 6 along the disk surface" having the angle θ = 2 - 30° exists in the area of the inside diameter surface 5 ranging from the end face of the inside diameter surface 5 on the small diameter end portion 2 side thereof to the range of 1/3A, within the portion of the inside diameter surface 5 that is relatively weak against the bending stress and the like due to the formation of the peripheral groove for the stop ring, the metal flow can be prevented from providing an end flow, which makes it possible to realize the further longer life of the disk 1.

[0059]

Further, since the "metal flow 6 along the disk surface" having the angle θ = 2 - 30° xists in the traction surface 4 in the range of an angle α of 45°, the area of the traction surface 4 that receives the severest bending stress and the like in the

traction surface 4 (see the fine hatching portion in Fig. 17) is covered by the "metal flow 6 along the disk surface", thereby being able to prevent effectively the breakage of the disk 1 caused by the bending stress and the like.

[0060]

Next, description will be given below of a method for manufacturing the disk 1 with reference to Figs. 2 to 5.

(First Step)

In Fig. 2, there is shown a first step (a swaging step) employed in the present disk manufacturing method. In particular, the left half section of Fig. 2 shows a state before the blank material is swaged, whereas the right half section of Fig. 2 shows a state after the blank material is swaged. In the first step, a cylindrical blank material (carburizing steel or the like) W1 with metal flows 6 existing on the outer peripheral surface of the blank material and extending along the axial direction of the blank material is interposed between an upper mold 11 and a lower mold 12; and, next, the upper mold 11 is moved in the axial direction of the cylindrical-shaped blank material W1 to swage the present cylindrical-shaped blank material W1, thereby molding the same into a blank material W2 having such a shape as shown in the right half section of Fig. 2. Here, in the first step, a swaging ratio is set larger than an ordinary swaging ratio; and, in this case, if the height H1 of the central portion of the blank material W2 after swaged is set in the range of 80 - 120% of the height H2 of a blank material W4 which is shown in Fig. 4 and is obtained when the forging operation is completed, then the lives of forging molds used in second and third steps (which will be discussed later) can be enhanced effectively.

[0061]

In the plane portion 12a of the lower mold 12, there is formed a recessed portion 13 into which the lower end portion of the cylindrical-shaped blank material W1 can be fitted; that

is, if the lower end portion of the cylindrical-shaped blank material W1 is fitted into the recessed portion 13, then the cylindrical-shaped blank material W1 can be aligned with the lower mold 12 with accuracy. Also, in the central portion of the upper mold 11, there is provided a circular projecting portion 14 having a diameter smaller than the diameter of the cylindrical-shaped blank material W1; and, the circular projecting portion 14, in the swaging operation, molds the central portion of the cylindrical-shaped blank material W1 to thereby spread the diameter of the blank material. Further, between the outer peripheral side plane portion 11a of the circular projecting portion 14 of the upper mold 11 and the circular projecting portion 14, there is formed a curve molding surface 15 which is curved outwardly in the diameter direction of the upper mold from the circular projecting portion 14 in such a manner as to expand gradually and upwardly and also which continues with the plane portion 11a of the upper mold. The present curve molding surface 15 is capable of transferring the curved shape to the swaged blank material W2.

(Second Step: Intermediate Step)

Now, Fig. 3 shows a second step employed in the present disk manufacturing method; and, the left half section of Fig. 3 shows a state of the blank material before molded, whereas the right half section thereof shows a state of the blank material after molded.. The function of the second step is to give the optimum shape to the blank material in order that the volume of the blank material can be distributed properly, that is, in order to be able to prevent the reduced thickness and burrs from occurring in a third step. If the shape of the blank material formed in the second step is not proper, then, when the blank material is molded in the third step, the burrs or the reduced thickness can be generated on the inside diameter corners (on the upper end side) of the blank material, or burrs on the outside diameter surface of the large diameter end portion of the blank

material (which will be discussed later) can be reduced in the thickness thereof. Also, another function of the second step is to give the blank material such a shape which allows alignment to be achieved positively between the blank material W3 and mold in the third step.

[0062]

Referring firstly to upper and lower molds 21 and 22 employed in the second step, in the central portion of the plane portion 21a of the upper mold 21, there is projectingly disposed a middle mold 25 which consists of a substantially conical-shaped projection. On the other hand, the lower mold 22 includes, in the portion thereof that is located near the outer periphery thereof, an inclined portion 23 which is inclined obliquely upwardly, that is, outwardly in the diameter direction of the blank material W2 swaged in the first step; and, the blank material W2 can be aligned with the lower mold 22 where the lower end side outer peripheral edge of the blank material W2 is in contact with the inclined portion 23 of the lower mold 22. At the then time, the lower end face of the blank material W2 is set in such a manner as to float slightly from the upper end face of a projecting portion 24 provided on the central plane portion 22a of the lower mold 22.

[0063]

And, in this state, if the upper mold 21 and middle mold 25 are moved down integrally, then not only the middle mold 25 invades into the upper end face central portion of the blank material W2 to thereby form a recessed portion 5a which is a portion of the inside diameter surface 5, but also the plane portion 21a of the upper mold 21 presses against the upper end face of the blank material W2 to thereby apply a molding pressure; and, due to this molding pressure, as shown in the right half section of Fig. 3, the shapes of the plane portion 22a, inclined portion 23 and projecting portion 24 of the lower mold 22 are respectively transferred to the lower end portion of the blank

material W2, so that the blank material W2 is molded into the shape of the blank material W3.

(Third Step)

Now, Fig. 4 shows a third step employed in the present disk manufacturing method; and, in particular, the left half section of Fig. 4 shows a state of the blank material before molded, whereas the left half section thereof shows a state of the blank after molded. In the third step, an upper mold 31 includes a small diameter end portion molding surface 33 for molding the small diameter end portion 2 of the disk 1, a traction surface molding surface 34 for molding the traction surface 4 having a concavo-arc-shaped cross section, and a middle mold 35 which is disposed in the central portion of the small diameter end portion molding surface 33 and is used to mold a portion of the inside diameter surface 5 from the small diameter end portion 2 side; and, a lower mold 32 includes a large diameter end portion molding surface 36 for molding the large diameter end portion 3, and a projecting portion 37 which is disposed in the central portion of the large diameter end portion molding surface 36 concentrically with the middle mold 35. Onto the projecting portion 37, there can be fitted the recessed portion 26 of the blank material W3 to which the shape of the projecting portion 24 of the lower mold 22 was transferred in the second step. That is, if the recessed portion 26 is fitted with the projecting portion 37, then the blank material W3 can be positioned in the central portion of the lower mold 32 accurately and positively. Also, on the outer peripheral portion of the lower mold 32, there is disposed an outer mold 38; and, the outer mold 38 and lower mold 32 cooperate together in forming a recess-shaped large diameter end portion molding space.

[0064]

And, in this state, if the upper mold 31 and middle mold 35 are moved down integrally, then not only the shapes of the small diameter end portion molding surface 33, traction surfac

molding surface 34 and large diameter end portion molding surface 35 are respectively transferred to the blank material W3, but also the middle mold 35 invades into the recessed portion 5a of the blank material W3 to thereby mold a recessed portion 5b, that is, a portion of the inside diameter 5 with a residual wall 39 left between the lower end side recessed portion and the recessed portion 5b. Thanks to this, as shown in the right half section of Fig. 4, the blank material W3 is molded into a blank material W4 having a shape approximate to the final shape of the disk 1. By the way, in the third step, at the time when the molding is completed, there is formed a clearance C between the upper mold 31 and outer mold 38 to thereby allow a bur S to be produced on the outside diameter surface of the large diameter end portion 3. That is, the production of the bur S can avoid a tightly closed forging operation to thereby prevent an unnecessary molding load from increasing, which makes it possible to improve the lives of the molds used.

[0065]

In the mold forged product W4 obtained in the above manner, in a post-step, from a state shown by a two-dot chained line in Fig. 5, the burr S is trimmed and removed by a press and the residual wall 39 of the inside diameter surface 5 is removed by a press; and, after then, the whole surface of the mold forged product W4 is ground so that it is molded into the disk 1 having the final shape shown by a solid line in Fig. 5. And, after the disk 1 is molded in this manner, the disk 1 is carburized or carbonitrided, that is, the disk 1 is heat treated and further the heat treated disk 1 is ground in such a manner as to have a required precision, before the disk 1 is incorporated into a troidal type continuously variable transmission.

[0066]

In the present disk manufacturing method, since the mold forging operation is carried out in three steps using three kinds of molds, the contact time between the molds and blank material

is shortened to thereby be able to reduce the heat influence on the molds in the molding operation. As a result of this, the mold surface hardness can be maintained in a good level, which in turn makes it possible to improve the lives of the molds.

[0067]

Also, because the swaging amount of the cylindrical-shaped blank material W1 is set larger than the ordinary swaging amount in the first step, not only in the second step but also in the third step which requires a high molding load in order to obtain a state close to the shape of the product, the molding amount can be reduced, with the result that the working burdens of not only the forging molds 21 and 22 in the second step but also the forging molds 31 and 32 in the third step can be reduced, thereby being able to extend the lives of these forging molds.

[0068]

Further, since the swaging amount of the cylindrical-shaped blank material W1 is set larger than the ordinary swaging amount in the first step, the push-in degree of the middle mold 25 in the second step as well as the push-in degree of the middle mold 35 in the third step can be reduced, which makes it possible to enhance greatly the tool lives of the middle molds 25 and 35 which can be most susceptible to the heat influence of the material.

[0069]

Still further, due to the fact that the blank material is positioned at the molding centers of the molds accurately and positively in the respective steps including the first to three steps, the blank material can be always molded at a correct position to thereby obtain a mold forged product of high precision.

[0070]

Yet further, since the mold forging operation is carried out in three steps using three kinds of molds, the material flow in the forging operation can be set freely. As a result of this, if the shape that corresponds with the final shape of the disk

is set in the pre-steps (first and second steps), then a well-balanced mold forged product can be obtained.

[0071]

In addition, because the disk 1 is obtained by grinding the mold forged product W4, even if the forged product before it is ground is a rough forged product (for example, a hot-forged product and the like), the present disk manufacturing method is surely able to deal with such forged product. Also, since it is little necessary to pay attention to the abrasion of the molds (that is, since the molds can be used even if they are abraded to some degree), the costs of the molds can be reduced in the long run.

[0072]

Next, description will be given below of a troidal type continuously variable transmission disk which is a second embodiment according to the invention.

As shown in Fig. 6, the present disk (finished product) 51 includes a small diameter end portion 2, a large diameter end portion 3, and a traction surface 4 which is interposed between the small diameter end portion 2 and large diameter end portion 3 and has a concavo-arc shaped cross section; and, in the central portion of the end face of the disk on the small diameter end portion 2 side thereof, there is formed a through hole which extend through the disk 51 up to the back surface of the large diameter end portion 3, while the inner peripheral surface of the through hole is used as an inside diameter surface 5 of the disk. Here, with reference to Figs. 6 and 14, among the metal flows 6 that exist in the disk 51, a metal flow 6, which has such a positional r lationship with respect to the surface of the disk 51 that the m tal flow 6 on the traction surface 4 side has an angle θ of 2 - 30°, preferably, 5 - 20 with r spect to a tangent P of the traction surface 4, is defined as a "metal flow 6 along the disk surface". In the disk 51, "metal flow 6s along the disk surface" each having the angle θ = 2 - 30°

exist continuously in the end face of the disk 51 on the small diameter end portion 2 side thereof, in the traction surface 4, in the outside diameter surface of the large diameter end portion 3, and in the back surface of the large diameter end portion 3; and, a "metal flow 6 along the disk surface" having the angle $\theta = 2 - 30°$ exists in the area of the inside diameter surface 5 ranging from the end face of the inside diameter surface 5 on the small diameter end portion 2 side thereof to the range of 1/3A, where the length of the disk 51 in the axial direction thereof is expressed as A.

[0073]

By the way, a metal flow 6 having the angle θ of greater than 30° with respect to the tangent P of the traction surface 4 becomes equivalent to an end flow (a metal flow which does not exist along the disk surface), so that such metal flow not only causes the material to peel off but also gives rise to the bending fatigue of the disk and thus the rupture of the disk (the lowered crack life).

[0074]

Also, in the present disk 51, with reference to Figs. 10 and 15, when the power roller is set horizontal (that is, parallel to the axis of the disk), that is, where the minor radius of the contact ellipse between the traction surface and power roller is expressed as b when a speed change ratio is 1:1, a nonmetal interposition 52 of high density exists in an area which is distant by 1.5b or longer in the depth direction from the traction surface.

Further, no interposition is present in an area which exits within the range of 1/3A (A is the length of the disk 51 in the axial direction thereof) from the end face of the inside diameter surface 5 on the small diameter end portion 2 side thereof.

[0075]

In the thus structured disk 51, since the "metal flow 6s along the disk surface" each having the angle $\theta = 2 - 30°$

exist continuously in the traction surface 4 with which the power roller can be fictionally engaged with a large pressure, especially when the disk 51 is used under a high load condition, not only the material in the engaged portion of the traction surface 4 where it is fictionally engaged with the power roller can be prevented from peeling off, but also an impact crack or a fatigue crack is hard to occur in the disk 51 so that the long life of the disk 51 can be realized.

[0076]

Also, because the "metal flow 6 along the disk surface" having the angle θ = 2 - 30° exists in the area of the inside diameter surface 5 ranging from the end face of the inside diameter surface 5 on the small diameter end portion 2 side thereof to the range of 1/3A, within the portion of the inside diameter surface 5 that is relatively weak against the bending stress and the like due to the formation of the peripheral groove for the stop ring, the metal flow can be prevented from providing an end flow; and, at the same time, since the "metal flow 6 along the disk surface" having the angle θ = 2 - 30° exists in the end face of the disk 51 on the small diameter end portion 2 side thereof as well, the bending fatigue as well as the concentration of the stress on the peripheral groove can be relieved, which makes it possible to extend the life of the disk 51 further.

[0077]

Further, the nonmetal interposition 52 of high density is not present not only in the area of the traction surface 4 that extends within the range of 1.5b in the depth direction from the traction surface and receives the severest shearing stress in the traction surface, but also in the portion of the inside diameter surface 5 that extends axially within the range of 1/3A from the small diameter end portion side end face of the inside diameter surface that can be affected severely by the bending stress or the like due to the formation of the peripheral groove for the stop ring and the like. This can avoid the ill

effects of the nonmetal interposition on the life of the disk 51.

[0078]

Next, description will be given below of a method for manufacturing the disk 51 with reference to Figs. 7 to 9.

(First step: Swaging step)

Now, Fig. 7 shows a first step (a swaging step) employed in the present disk manufacturing method; and, in particular, the left half section of Fig. 7 shows a state of a blank material before swaged, whereas the right half section of Fig. 7 shows a state thereof after swaged. In the first step, a cylindrical blank material (carburizing steel or the like) W11 with metal flows 6 existing on the outer peripheral surface of the blank material and extending along the axial direction of the blank material is interposed between an upper mold 51 and a lower mold 52; and, next, the upper mold 51 is moved in the axial direction of the cylindrical-shaped blank material W11 to swage the present cylindrical-shaped blank material W11, thereby molding the same into a blank material W12 having such a shape as shown in the right half section of Fig. 7.

[0079]

In the plane portion 52a of the lower mold 52, there is formed a recessed portion 53 into which the lower end portion of the cylindrical-shaped blank material W11 can be fitted; that is, if the lower end portion of the cylindrical-shaped blank material W11 is fitted into the recessed portion 53, then the cylindrical-shaped blank material W11 can be aligned with the lower mold 52 accurately and positively.

[0080]

On the other hand, in the central portion of the upper mold 51, there is formed a tapered recessed portion 51a which decreases in diameter in the upward direction thereof in such a manner as to be concentric with the recessed portion 53 of the lower mode 52, while the bottom surface of the present tapered

recessed portion 51a is formed as a flat surface 54. And, the peripheral edge (a boundary portion between the outer peripheral surface and upper end face of the cylindrical-shaped blank material W11) of the upper end face of the cylindrical-shaped blank material W11 is in contact with the slanting portion 55 of the tapered recessed portion 51a. Thanks to this, when the upper mold 51 is moved down, the upper mold 51 restricts the upper end portion of the cylindrical-shaped blank material W11 to thereby be able to not only align the cylindrical-shaped blank material W11 with the upper mold 51 accurately and positively but also transfer the shape of the slanting portion 55.

(Second step)

Now, Fig. 8 shows a second step employed in the present disk manufacturing method; and, in particular, the left half section of Fig. 8 shows a state of the blank material before molded, whereas the right half section of Fig. 8 shows a state thereof after molded. In the second step, the blank material W12 swaged in the first step is interposed between a lower mold 62 and an upper mold 61 mounted on an outer mold 65 and the upper mold 61 is moved in the axial direction of the blank material W12 to thereby mold the blank material W12 into a blank material W13 which has such a shape approximate to the final shape of the disk 51 as shown in the right half section of Fig. 8.

[0081]

The lower mold 62 includes a large diameter end portion molding surface 63 for molding the large diameter end portion 3 of the disk 51 and, in the central portion of the large diameter end portion molding surface 63, there is a recessed portion 64 into which a projecting portion 56 (to which the shape of the recessed portion 53 of the lower mold 52 was transferred in the first step) can be fitted. That is, if the projecting portion 56 of the blank material W12 is fitted into the recessed portion 64 of the lower mold 62, then the blank material W12 is prevented from playing with respect to the lower mold 62 so that the alignment

of the blank material W12 with the lower mold 62 can be achieved accurately and positively.

[0082]

The outer mold 65 includes a small diameter end portion molding surface 66 for molding the small diameter end portion 2 of the disk 51 and a traction surface molding surface 67 for molding the traction surface 4; and, in the central portion of the small diameter end portion molding surface 66, there is projectingly provided the upper mold 61 having a cylindrical shape.

[0083]

In the lower end face of the upper mold 61, there is formed a shallow tapered recessed portion 68 which reduces gradually in diameter as it goes upwardly. The bottom surface of the tapered recessed portion 68 is formed as a flat surface 69 and the diameter of the flat surface 69 is set larger than the area diameter of a nonmetal interposition 52 of high density which exists in the central portion of the upper end face of the blank material W12 swaged in the first step. Also, since the outer peripheral surface of the upper end portion of the blank material W12 is in contact with the slanting portion 70 of the tapered recessed portion 68, the alignment of the blank material W12 with the upper mold 61 can be achieved accurately and positively. Therefore, the inside diameter D2 of the slanting portion 70 of the tapered recessed portion 68, in particular, the inside diameter D2 of the contact position of the slanting portion 70 with the blank material W12 is larger than the diameter D1 of the upper end face of the blank material W12.

[0084]

And, in this state, if the outer mold 65 and upper mold 61 are moved down integrally, then not only the shapes of the small diameter end portion molding surface 66, traction surface molding surface 67 and large diameter end portion molding surface 63 are r spectively transferred to the blank material W12, but

also the upper mold 61 invades into the central portion of the blank material W12 to thereby mold a recessed portion 5d, that is, a portion of the inside diameter 5 with a residual wall 71 left between the recessed portion 64 and the present recessed portion 5d. Thanks to this, as shown in the right half section of Fig. 8, the blank material W12 is molded into a blank material W13 having a shape approximate to the final shape of the disk 51. By the way, in the second step, at the time when the molding is completed, there is formed a clearance C between the lower mold 62 and outer mold 65 to thereby allow a bur S to be produced on the outside diameter surface of the large diameter end portion 3. That is, the production of the bur S can avoid a tightly closed forging operation to thereby prevent an unnecessary molding load from increasing, which makes it possible to improve the lives of the molds used.

[0085]

Also, when the upper mold 61 invades into the central portion of the blank material W12, not only the tapered recessed portion 68 of the upper mold 61 restricts the upper end portion of the blank material W12 to thereby prevent the present upper end portion from increasing in diameter during molding, but also the nonmetal interposition 52 of high density existing in the central portion of the blank material W12 is pushed into the lower end side of the blank material W12 to thereby expand the present lower end side outwardly in the diameter direction of the blank material W12.

[0086]

In the mold forged product W13 obtained in the above manner, in a post-step, from a state shown by a two-dot chained line in Fig. 9, the burr S is trimmed and removed by a press and the residual wall 71 of the inside diameter surface 5 is removed by a press; and, after then, the whole surface of the mold forged product W13 is ground so that it is molded into the disk 51 having the final shape shown by a solid line in Fig.

9. And, after the disk 51 is molded in this manner, the disk 51 is carburized or carbonitrided, that is, the disk 51 is heat treated and further the heat treated disk 51 is ground in such a manner as to have a required precision, before the disk 51 is incorporated into a troidal type continuously variable transmission.

[0087]

As can be seen clearly from the above description, in the present disk manufacturing method, it is possible to obtain the disk 51 (finished product) simply and positively in which "metal flow 6s along the disk surface" each having the angle θ = 2 - 30° exist in the end face of the disk 51 on the small diameter end portion 2 side thereof, in the traction surface 4, in the outside diameter surface of the large diameter end portion 3, and in the back surface of the large diameter end portion 3.

[0088]

Also, not only since use of the mold forging method can reduce the diameter of the cylindrical-shaped blank material W11 in the first step, but also since, in the second step, the tapered recessed portion 68 of the upper mold 61 restricts the upper end portion of the blank material W12 to thereby prevent the present upper end portion from increasing in diameter during molding and also the nonmetal interposition 52 of high density existing in the central portion of the blank material W12 is pushed into the lower end side of the blank material W12 to thereby expand the present lower end side outwardly in the diameter direction of the blank material W12, there can be obtained the disk 51 simply and positively in which the nonmetal interposition 52 of high density is not present not only in the area of the traction surface 4 that extends within the range of 1.5b in the depth direction from the traction surface and receives the severest shearing stress in the traction surface, but also in the portion of the inside diameter surface 5 that xtends axially within

the range of 1/3A from the small diameter end portion side end face of the inside diameter surface that can be affected severely by the bending stress or the like due to the formation of the peripheral groove for the stop ring and the like.

[0089]

[Embodiments]

Now, Table 1 shows the results of a disk durability test in which, when it is assumed that a load is 5t and a load position is the groove bottom of the traction surface, the respective disks are tested in the durability thereof by changing the angle α (see Fig. 14). Here, the angle α is an angle formed between the traction surface 4 and a horizontal line passing through the center of curvature 0 (that is, a line extending in parallel to the axis of a disk).

[0090]

In Table 1, disks No. 1 to No. 6 are respectively embodiments according to the invention. In particular, in each of the disks No. 1 to No. 4, the "metal flow 6 along the disk surface" having the angle $\theta = 2 - 30°$ exists in the traction surface thereof. Also, among these disks, in the No. 1 and No. 2 disks, the angle is set such that $\alpha < 45°$ and, in the No. 3 and No. 4 disks, the angle is set such that $\alpha \geq 45°$. And, as the No. 5 and No. 6 disks, there were used disks in which the "metal flows 6 along the disk surface" having the angle $\theta = 2 - 30°$ exist continuously in the traction surface thereof. On the other hand, as the No. 7 and No. 8 disks, there were used conventional disks which were manufactured by cutting. Except for the above-mentioned conditions, the same test conditions (such as size, material, load condition and the like) were set for all the disks in the present disk durability test.

[0091]

By the way, the angle was adjusted to $\theta = 2 - 30$ by previously checking a metal flow after forged and by adjusting the margin. In particular, a metal flow having the angle θ smaller than

or equal to the angle α ° is assumed as a metal flow along the disk surface which satisfies the θ range according to the invention; and, a metal flow having the angle θ larger than the angle $\alpha°$ is assumed as a metal flow which has an angle out of the θ range according to the invention. That is, the disks were observed for breakage under the above conditions. The forged disks were manufactured by using the above-mentioned two manufacturing methods properly.

[0092]

Table 1

No.		α [deg.]	Test Result	Judgment
1	Embodiment	27	Broken in 123 hrs.	△
2	Embodiment	37	Broken in 194 hrs.	△
3	Embodiment	48	Vibrated in 289 hrs. Crack in traction surface	○
4	Embodiment	50	Vibrated in 272 hrs. Crack in traction surface	○
5	Embodiment	-	Nothing wrong in 350 hrs.	◎
6	Embodiment	-	Nothing wrong in 350 hrs.	◎
7	Conventional Example	-	Broken in 97 hrs.	×
8	Conventional Example	-	Broken in 63 hrs.	×

Load: approx. 5 ton

Load position: Groove bottom

[0093]

As can be seen clearly from Table 1, the disks (No. 1 to No. 6) according to the invention are greatly enhanced in the durability of the traction surface thereof when compared with the conventional disks (No. 7 and No. 8).

[0094]

Also, among the disks according to the invention, the disks having $\alpha \geq 45°$ (No. 3 and No. 4) are enhanced in durability when compared with the disks having $\alpha < 45°$; and, in the disks

(No. 5 and No. 6) in which the "metal flows 6 along the disk surface" having the angle $\theta = 2 - 30°$ exist continuously in the traction surface thereof, even after 350 hours have passed, there was found nothing wrong on the traction surface thereof, that is, it can well be said that they have the greatest durability.

[0095]

By the way, although the present durability test was finished in 350 hrs., in the disks having $\theta \fallingdotseq 0°$ and $\theta = 2°$, it is believed that nothing wrong can be found even after the passage of 350 hrs. and thus it can be expected that these disks are almost equivalent to the disks No. 5 and No. 6 in performance.

Now, Table 2 shows the results of a second disk durability test in which the depth of a disk ranging from the traction surface thereof to the area of the high-density nonmetal interposition (a 0.3D portion: see Figs. 10 and 12) is caused to vary. By the way, in Table 2, b designates the minor radius of the contact ellipse between the traction surface and power roller when a speed change ratio is 1:1 (see Fig. 15).

[0096]

In Table 2, disks No. 1 to No. 8 are all embodiments according to the invention and, for each of the disks, there was used a disk in which the "metal flow 6 along the disk surface" having the angle $\theta = 2 - 30°$ exists in the traction surface thereof. The present durability test was conducted for all disks under the same conditions, except that the depth of a disk ranging from the traction surface thereof to the area of the high-density nonmetal interposition varies in the respective disks.

[0097]

Table 2

No.	Depth of 0.3D portion from surface	Test Result	Judgment
1	0	Traction surface peels off in 170 hrs.	△
2	0.25b	Traction surface peels off in 173 hrs.	△
3	0.60b	Traction surface peels off in 212 hrs.	○
4	0.90b	Traction surface peels off in 208 hrs.	○
5	1.25b	Traction surface peels off in 239 hrs.	○
6	1.6b	Nothing wrong in 250 hrs.	◎
7	2.55b	Nothing wrong in 250 hrs.	◎
8	4.5b	Nothing wrong in 250 hrs.	◎

b: Small radius of contact ellipse between traction surface and power roller when speed change ratio is 1:1

[0098]

As can be clearly understood from Table 2, as the depth of the 0.3D portion from the traction surface to the high-density nonmetal interposition area increases, the durability of the traction surface is enhanced and, especially, the depth is larger than or equal to 1.5 b, nothing wrong is found even after 250 hrs. have passed, which shows that the traction surface having the depth larger than or equal to 1.5 b is most excellent in durability.

[0099]

Now, Table 3 shows the results of a third durability test conducted on disks which are different from each other in the existing area of the high-density nonmetal interposition of the disk inside diameter surface, in particular, on the durability of the inside diameter surfaces of the disks on their respective small diameter end portion sides. Here, A expresses the axial length of the disk (that is, the length of the disk in the axial direction thereof), and B expresses the axial length

of the inside diameter surface from the end face of the inside diameter surface on the small diameter end portion side thereof.

[0100]

In Table 3, No. 3 to No. 8 test pieces are disks which were manufactured according to the embodiments of the invention. In the present durability test, as the embodiments of the invention, there were used disks in each of which the "metal flow 6 along the disk surface" having the angle $\theta = 2 - 30°$ exists in the inside diameter surface thereof in the range from the small diameter end portion side end face of the inside diameter surface to the axial depth of (B/A) x 100% where the axial length of the disk is expressed as A. Also, as No. 1 and No. 2 disks, there were used conventional disks which were manufactured by cutting. That is, in the present durability test, all disks were tested under the same conditions, except that the disks differ from each other in the existing area of the high-density nonmetal interposition of the disk inside diameter surface. By the way, in the disks No. 3 to No. 8, the relationship between the nonmetal interpositions and their respective existing area (B/A) x 100% were adjusted by adjusting the margins of the respective disks when they were manufactured. In this case as well, as the test disks, there were properly used forged disks which were manufactured according to the above-mentioned two manufacturing methods.

[0101]

Table 3

No.		Working Method	(B/A) ×100 [%]	Test Result	Judgment
1	Conventional Example	Cutting	-	Inside diameter portion on small diameter side was broken in 68 hrs.	×
2	Conventional Example	Cutting	-	Inside diameter portion on small diameter side was broken in 59 hrs.	×
3	Embodiment	Forging	15	Inside diameter portion on small diameter side was broken in 171 hrs.	△
4	Embodiment	Forging	22	Inside diameter portion on small diameter side was broken in 211 hrs.	○
5	Embodiment	Forging	34	No problem after passage on 250 hrs.	◎
6	Embodiment	Forging	41	No problem after passage on 250 hrs.	◎
7	Conventional Example	Forging	53	No problem after passage of 250 hrs.	◎
8	Conventional Example	Forging	51	No problem after passage of 250 hrs.	◎

[0102]

As can be seen obviously from Table 3, the disks (No. 3 to No. 8) according to the invention are greatly improved in the durability of the inside diameter surface on the small diameter end portion side thereof when compared with the conventional disks (No. 1 and No. 2).

[0103]

Also, out of the disks according to the invention, in the disks in which the high-density nonmetal interposition exists in the inside diameter surface over the ((B/A) x 100%) area of more than 33%, nothing wrong was found in the small diameter end portion side inside diameter surface thereof even after the passage of 250 hrs., which shows s that these disks are most excellent in durability.

[0104]

[Effects of the Invention]

As can be clearly understood from the foregoing description, according to the invention, there can be provided a troidal type

continuously variable transmission disk which not only permits the reduction of the production cost thereof but also can extend the life thereof.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1]

Fig. 1 is an is an explanatory view of a troidal type continuouslyvariabletransmissiondiskwhichisafirstembodiment according to the invention;

[Fig. 2]

Fig. 2 is an explanatory view of a first step employed in a disk manufacturing method, in particular, the left half section of Fig. 2 shows a state of a disk blank material before molded, while the right half section thereof shows a state of a disk blank material after molded;

[Fig. 3]

Fig. 3 is an explanatory view of a second step employed in the disk manufacturing method, in particular, the left half section of Fig. 3 shows a state of a disk blank material before molded, while the right half section thereof shows a state of a disk blank material after molded;

[Fig. 4]

Fig. 4 is an explanatory view of a third step employed in the disk manufacturing method, in particular, the left half section of Fig. 4 shows a state of a disk blank material before molded, while the right half section thereof shows a state of a disk blank material after molded;

[Fig. 5]

Fig. 5 is an explanatory view of an example of a final step employed in the disk manufacturing method;

[Fig. 6]

Fig. 6 is an explanatory vi w of a troidal type continuously variable transmission disk which is a second embodiment according to the invention;

[Fig. 7]

Fig. 7 is an explanatory view of a first step employed in a disk manufacturing method, in particular, the left half section of Fig. 7 shows a state of a disk blank material before molded, while the right half section thereof shows a state of a disk blank material after molded;

[Fig. 8]

Fig. 8 is an explanatory view of a second step employed in the disk manufacturing method, in particular, the left half section of Fig. 8 shows a state of a disk blank material before molded, while the right half section thereof shows a state of a disk blank material after molded;

[Fig. 9]

Fig. 9 is an explanatory view of an example of a final step employed in the disk manufacturing method;

[Fig. 10]

Fig. 10 is an an explanatory view of the existing portion of the high-density nonmetal interposition in a disk;

[Fig. 11]

Fig. 11 is a graphical representation to explain the relationship between the depth from the surface of a traction surface and the distribution of shearing stress;

[Fig. 12]

Fig. 12 is an an explanatory view of the existing portion of the high-density nonmetal interposition in a cylindrical-shaped blank material before molded;

[Fig. 13]

Fig. 13 is a graphical representation to explain the relationship between the diameter of the cylindrical-shaped blank material before molded and the number of interpositions;

[Fig. 14]

Fig. 14 is a view to explain the meanings of α and θ ;

[Fig. 15]

Fig. 15 is a section view to explain a troidal type

continuously variable transmission;

[Fig. 16]

Fig. 16 is an explanatory view of a conventional disk;

[Fig. 17]

Fig. 17 is an explanatory view of a portion of a disk which receives large repeated bending stress and repeated shearing stress;

[Fig. 18]

Fig. 18 is an explanatory view of a conventional disk manufacturing disk; and,

[Fig. 19]

Fig. 18 is an explanatory view of another conventional disk manufacturing disk.

[Description of Reference Characters]

1, 51: Disk

2: Small diameter end portion

3: Large diameter end portion

4: Traction surface

6: Metal flow

c: Power roller

P: Tangent

θ : Angle formed between tangent of traction surface and metal flow

Fig. 11

Shearing stress (distribution)

Surface (contact surface) Depth

Fig. 13

Number of interpositions (interpositions of 10μ m or larger/300 mm^2

Diameter

Fig. 14

Horizontal line Metal flow Traction surface

Fig. 16

High-density nonmetal interposition

Fig. 17

Stop ring

【図7】ディスクの製法の第1工程を説明するための説明図であり、左半分は成形前の状態、右半分は成形後の状態を表している。

【図8】ディスクの製法の第2工程を説明するための説明図であり、左半分は成形前の状態、右半分は成形後の状態を表している。

【図9】ディスクの製法の最終工程の一例を説明するための説明図である。

【図10】ディスクにおける高密度の非金属介在物の存在箇所を説明するための説明図である。

【図11】トラクション面の表面からの深さとせん断応力の分布との関係を説明するためのグラフ図である。

【図12】成形前の円柱素材における高密度の非金属介在物の存在箇所を説明するための説明図である。

【図13】成形前の円柱素材における直径と介在物の数との関係を説明するための説明図である。

【図14】αとθの意味を説明するための説明図である。

【図15】トロイダル型無段変速機を説明するための説明的断面図である。

【図16】従来のディスクを説明するための説明図である。

【図17】ディスクにおいて大きな繰り返し曲げ応力や繰り返しせん断応力を受ける部分を説明するための説明図である。

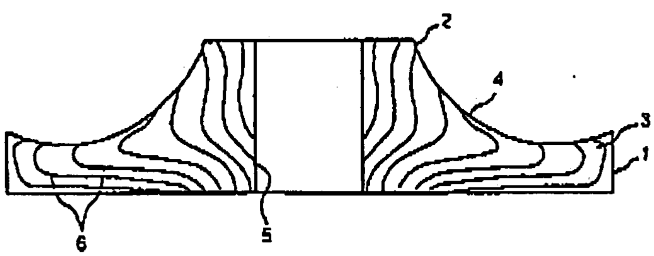
【図18】従来のディスクの製法を説明するための説明図である。

【図19】従来の他のディスクの製法を説明するための説明図である。

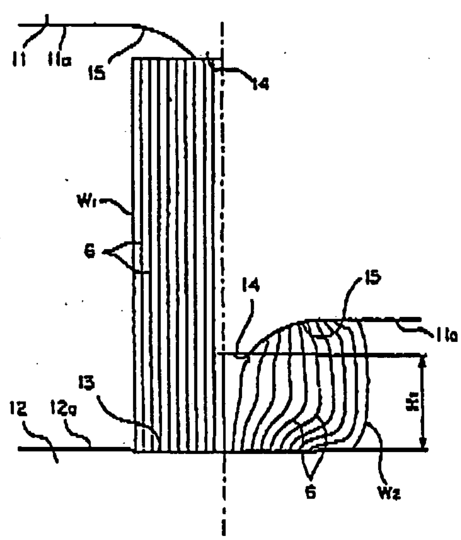
【符号の説明】

1．51…ディスク
2…小径端部
3…大径端部
4…トラクション面
6…メタルフロー
c…パワーローラ
P…接線
θ…トラクション面の接線とメタルフローとのなす角度

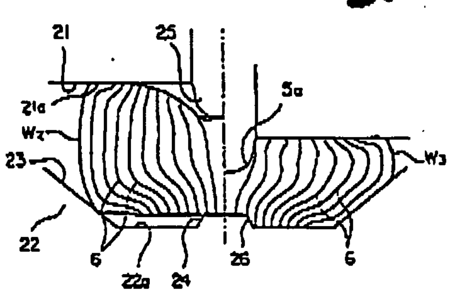
~~【図1】~~ Fig.1



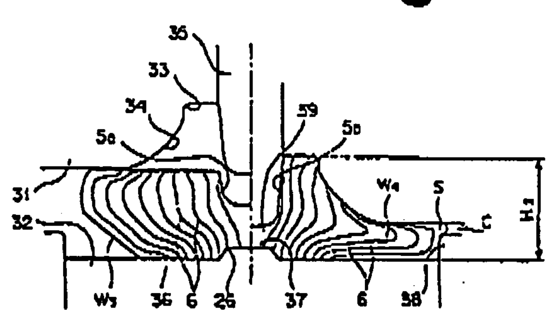
~~【図2】~~ Fig.2



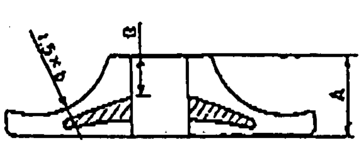
~~【図3】~~ Fig.3



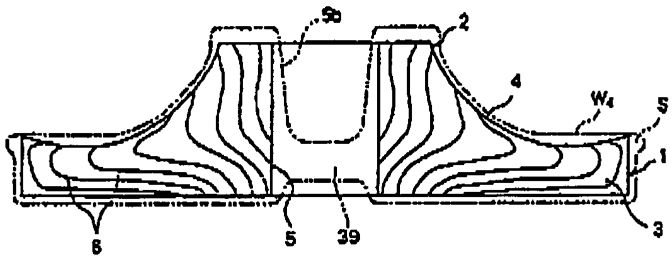
~~【図4】~~ Fig.4



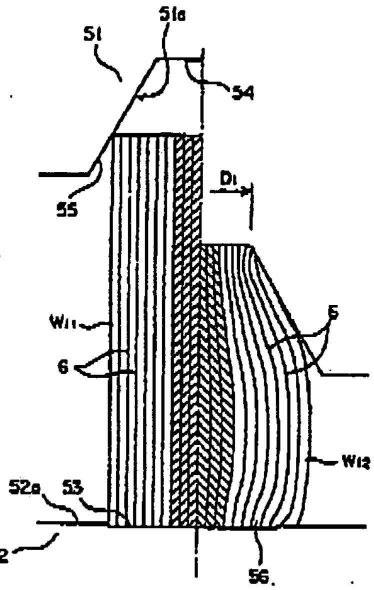
~~【図10】~~ Fig.10



~~【図5】~~ Fig.5



~~【図7】~~ Fig.7



~~【図6】~~ Fig.6

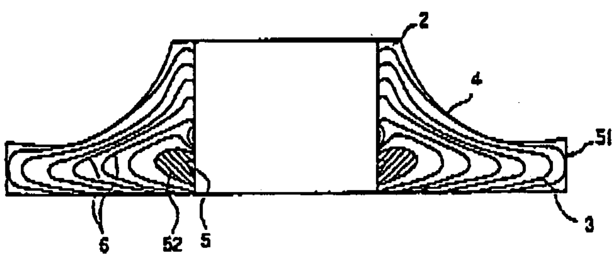
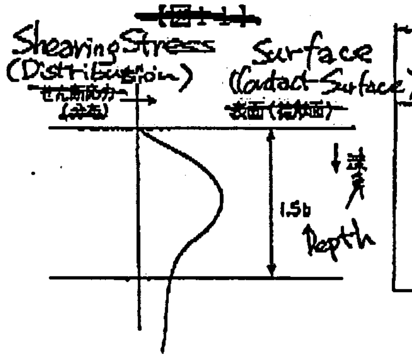
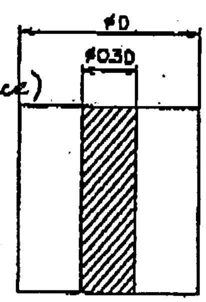


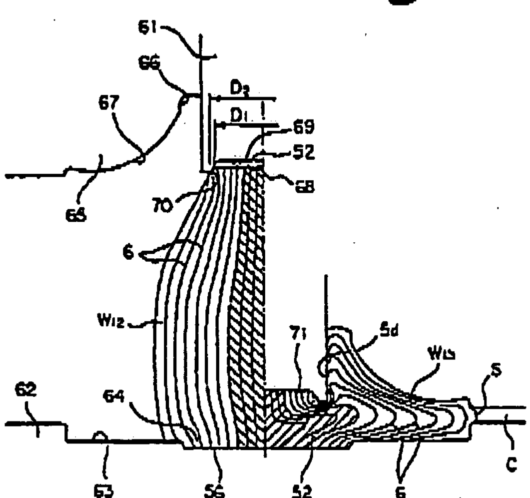
Fig.11 ~~【図11】~~



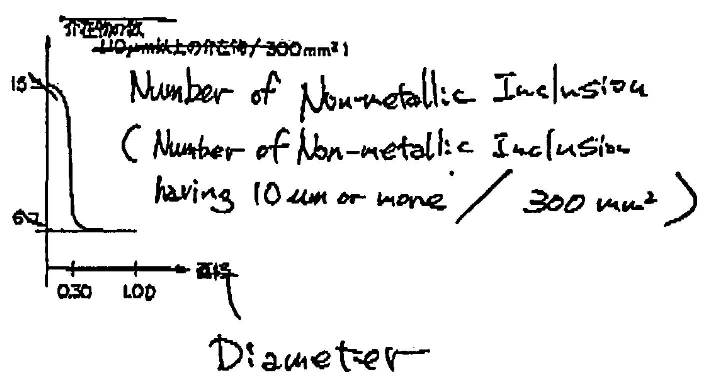
~~【図12】~~ Fig.12



~~【図8】~~ Fig.8



~~【図13】~~ Fig.13



~~【図16】~~ Fig.16

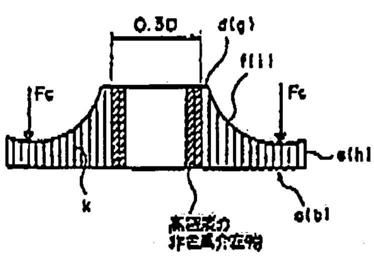


Fig. 9

~~【図9】~~

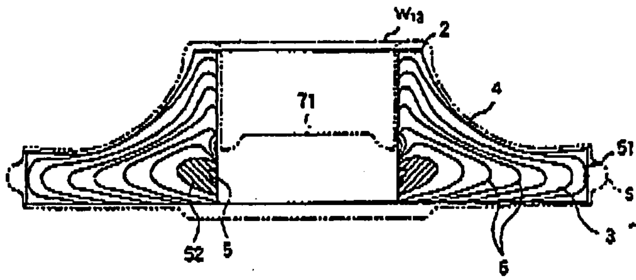


Fig. 14

~~【図14】~~

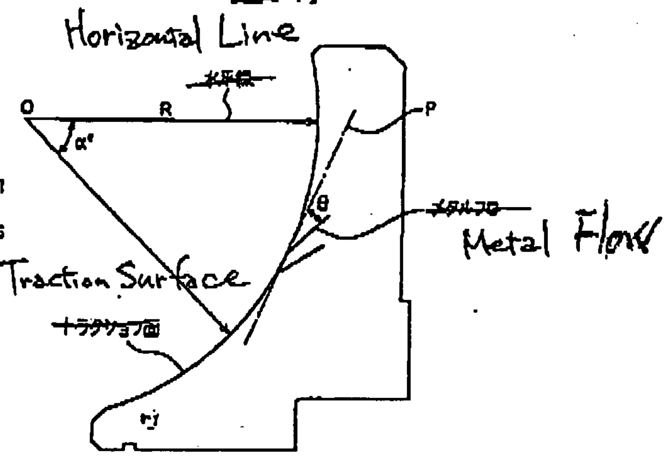


Fig. 15

~~【図15】~~

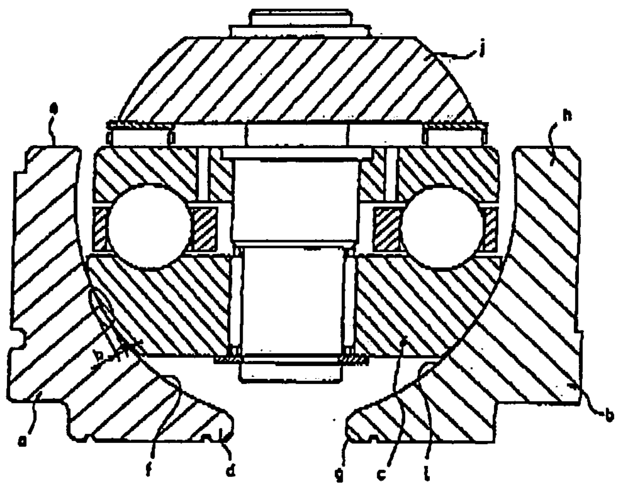


Fig. 17

~~【図17】~~

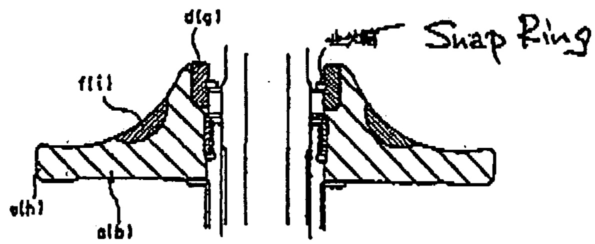
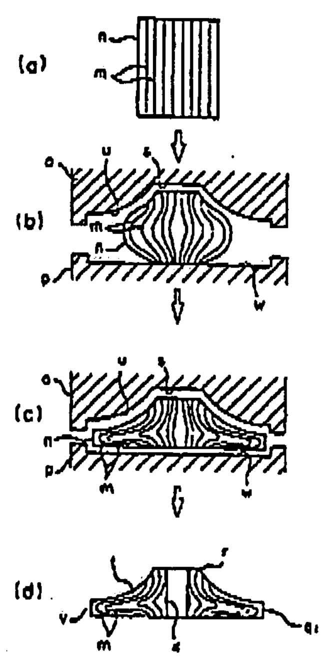
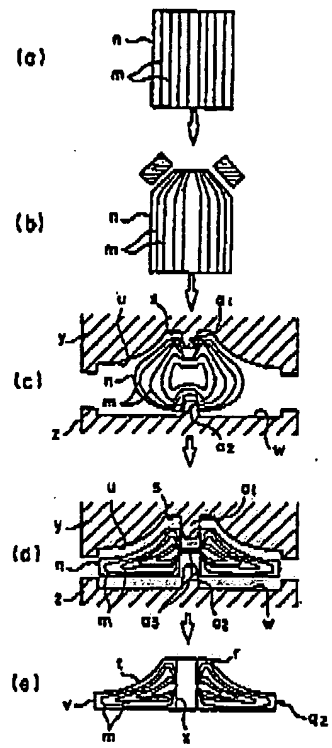


Fig. 18

~~【図18】~~



~~【図19】~~ Fig. 19



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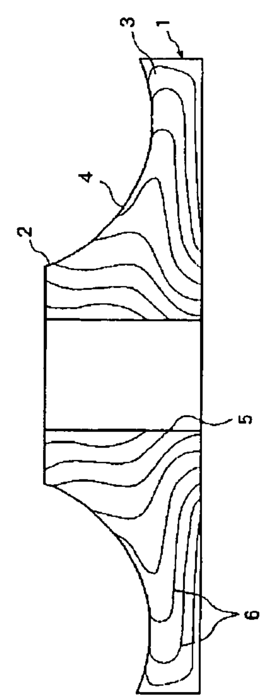
最終頁に続く

(54)【発明の名称】　トロイダル型無段変速機のディスク

(57)【要約】

【課題】　生産コストの低減を可能にするとともに、長寿命化を図ることができるトロイダル型無段変速機のディスクを提供する。

【解決手段】　ディスク１は小径端部２と大径端部３との間に断面円弧凹状のトラクション面４を備えており、小径端部２側の端面中心部には大径端部３側の端面まで貫通する穴が形成されて該穴の内周面が内径面５とされている。ここで、ディスク１に存在するメタルフロー６のうちで、トラクション面４側のメタルフロー６と該トラクション面４の接線とのなす角度θが３０°以下になるような位置関係をディスク１の表面に対して有するメタルフロー６を「ディスク表面に沿うメタルフロー６」と定義した場合に、「ディスク表面に沿うメタルフロー６」が少なくともトラクション面４に存在するように構成する。



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【特許請求の範囲】

【請求項１】 小径端部と大径端部との間に断面円弧凹状のトラクション面が形成され、該トラクション面を互いに対向させた状態で同軸配置された入力及び出力ディスクと、該入力及び出力ディスクの各トラクション面に摩擦係合して動力の伝達を行うパワーローラとを備えたトロイダル型無段変速機において、前記トラクション面側のメタルフローと該トラクション面の接線とのなす角度θが３０°以下になるような位置関係を前記ディスク表面に対して有するメタルフローを該ディスク表面に沿うメタルフローと定義した場合に、前記ディスクの表面に沿うメタルフローを少なくとも前記トラクション面に備えたことを特徴とするトロイダル型無段変速機のディスク。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、自動車や各種産業用機械等に用いられるトロイダル型無段変速機のディスクに関する。

【０００２】

【従来の技術】トロイダル型無段変速機は、例えば、図１５に示すように、互いに同軸配置された入力及び出力ディスクａ，ｂと、入力及び出力ディスクａ，ｂの各トラクション面ｆ，ｉ間に介在されたパワーローラｃとを備える。

【０００３】入力ディスクａは小径端部ｄと大径端部ｅとの間に断面円弧凹状のトラクション面ｆが形成され、出力ディスクｂも同様に小径端部ｇと大径端部ｈとの間に断面円弧凹状のトラクション面ｉが形成されている。入力ディスクａのパワーローラｃから離間する側には複数の係合ローラを介してローディングカム（共に図示せず。）が同心に配置されており、ローディングカムと入力ディスクａとの間に供給された油圧により、トルクに比例した入力ディスクａ側への推力を付与するようにしている。

【０００４】パワーローラｃは、入力及び出力ディスクａ，ｂの各トラクション面ｆ，ｉに摩擦係合して動力の伝達を行うものであり、トラニオンｊによってディスクａ，ｂの径方向に傾動可能に支持されている。そして、図示しない駆動機構でトラニオンｊを操作してパワーローラｃの入力及び出力ディスクａ，ｂに対する径方向の接触位置を変えることにより、入力ディスクａと出力ディスクｂとの間の回転速度比、即ち変速比を連続的に変化させることができるようになっている。

【０００５】ところで、トロイダル型無段変速機は、より高いトルクの伝達が必要とされており、このため、入力及び出力ディスクａ，ｂとパワーローラーｃは、通常

2

の機械部品（一般的なギア、軸受）に比べて非常に大きな繰り返し曲げ応力や繰り返しせん断応力を受け、入力及び出力ディスクａ，ｂについては、特に、図１７に細いハッチングで示すように、トラクション面ｆ，ｉ、小径端部ｄ及び該小径端部ｄ側の内径面が大きな繰り返し曲げ応力や繰り返しせん断応力を受ける。従って、入力及び出力ディスクａ，ｂの製造に際しては、これらの繰り返し曲げ応力や繰り返しせん断応力に影響されないような耐久性の高い材料を用いる必要がある。

【０００６】入力及び出力ディスクａ，ｂを製造するには、例えば図１２に示すような入力及び出力ディスクａ，ｂの軸長と同じ長さの円柱素材（浸炭鋼等）を、削り出しや切り出しによって図１６に示すような最終形状に加工している。

【０００７】

【発明が解決しようとする課題】しかしながら、従来の入力及び出力ディスクａ，ｂの製造方法においては、材料の歩留りが悪く、しかも、切削時間も長時間を要するため、生産コストが高騰するという不都合がある。

【０００８】また、メタルフロー（組織の流れ）ｋが軸線方向に沿って配置されるため、パワーローラｃが大きな圧力で摩擦係合するトラクション面ｆ，ｉにおいてメタルフローｋが途切れてしまって該トラクション面ｆ，ｉに沿う部分がなくなり、この結果、トラクション面ｆ，ｉのパワーローラｃの摩擦係合部分に材料の剥離が生じやすくなるとともに、メタルフローｋの分断箇所が破壊の起点となって、入力及び出力ディスクａ，ｂに衝撃割れや疲労割れが発生しやすくなり、入力及び出力ディスクａ，ｂの長寿命化を妨げる原因になるという不都合がある。

【０００９】本発明はかかる不都合を解消するためになされたものであり、生産コストの低減を可能にするとともに、長寿命化を図ることができるトロイダル型無段変速機のディスクを提供することを目的とする。

【００１０】なお、円柱素材の中心及び中心近傍の部分（図１２及び図１６において０．３Ｄ部分：Ｄは円柱素材の直径）は疲労破壊強度に大きな影響を及ぼす非金属介在物の密度が高いため（図１３参照）、該介在物がディスクの曲げ応力等の厳しい領域（例えば小径端部側の内径面）やトラクション面のうちで最も厳しいせん断応力を受ける領域に存在しないようすることが望まれる。

【００１１】非金属介在物について説明すると、材料の繰り返し曲げなどに対する材料強度には、その破壊の起点となる欠陥の大きさが大きく影響を及ぼすことが知られており、例えば「微小欠陥と介在物の影響」（村上著、１９９３年、養賢堂発行）には、繰り返し曲げが加わった場合の材料の疲労限度が

$$\sigma_w = \frac{K\,(Hv + 120)}{((area)^{1/2})^{1/6}} \quad \cdots (1)$$

K：1．43（欠陥が表面に存在する場合）
1．41（欠陥が表面に接するように存在する場合）
1．56（欠陥が内部に存在する場合）
σ_w：疲労限度
Hv：材料の硬さ（材料素材のマトリックスの強さに関するもの）
$(area)^{1/2}$：欠陥やき裂を最大主応力方向に投影した投影面積の平方根（欠陥やき裂の寸法を代表する量）
で表わせることが述べられている。

【0012】従って、トロイダル型無段変速機のような過酷な条件（大きな繰り返し曲げ応力と同時に大きな繰り返しせん断応力を受ける）で使用される機械部品においては、このような破壊の起点となる欠陥を管理した材料を使用することが望ましい。

【0013】一般に、高強度を必要とする鋼の主な欠陥原因は、酸化物系介在物であることが知られている。このような酸化物系介在物を管理する方法としては、ＪＩＳ法（ＪＩＳ－Ｇ－０５５５）やＡＳＴＭ法（ＡＳＴＭ－Ｅ４５）などが知られている。また、特に高清浄度を要求する軸受材料において、例えば特開平３－２９４４３５号公報に開示されているように電子ビーム溶解法を使つて材料を再溶解し、大きな酸化物系介在物を浮遊させて材料の清浄度を管理する方法や、「微小欠陥と介在物の影響」（村上著、１９９３年、養賢堂発行）に開示されている極値統計法（単位面積S_0あたりの最大酸化物系介在物径を数個の試験片から調査し、その後、統計処理を行なうことにより、必要とする面積Ｓでの推定最大酸化物系介在物怪を予測する方法）がある。

【0014】このような清浄度の管理方法を用いて、例えば転がり軸受やギアなどでは、その機能に十分対応できる鋼の清浄度管理が行われているが、トロイダル型無段変速機を構成するディスクやパワーローラにおいては、転がり軸受やギアなどのように通常の繰り返し応力を受ける機械部品に比べて応力の絶対値が大きく（接触面圧４．０ＧＰａ程度、曲げ応力９０ｋｇｆ／mm^2程度）、しかも、繰り返し曲げ応力と繰り返しせん断応力が同時に加わるとともに、応力を受ける体積が大きい。このため、トロイダル型無段変速機のディスクにおいては、このような介在物管理法では十分な強度を得ることが困難であり、従って、介在物の影響を受けないようするための新たな手段が望まれる。

【0015】

【課題を解決するための手段】かかる目的を達成するために、本発明に係るトロイダル型無段変速機のディスクは、小径端部と大径端部との間に断面円弧凹状のトラクション面が形成され、該トラクション面を互いに対向させた状態で同軸配置された入力及び出力ディスクと、該＊＊入力及び出力ディスクの各トラクション面に摩擦係合して動力の伝達を行うパワーローラとを備えたトロイダル型無段変速機において、全ての仕上加工が行われた完成状態での前記トラクション面側のメタルフローと該トラクション面の接線とのなす角度θの上限値を３０°以下、好ましくは２０°以下になるような位置関係を前記ディスク表面に対して有するメタルフローを該ディスク表面に沿うメタルフローと定義した場合に、前記ディスクの表面に沿うメタルフローを少なくとも前記トラクション面に備えたことを特徴とする。

【0016】ここで、トラクション面の接線とのなす角度θが３０°を越えるメタルフローは、エンドフロー（ディスク表面に沿わないメタルフロー）と同等となって材料の剥離を発生させるとともに、曲げ疲労等によるディスクの破壊（割れ寿命低下）を招く原因になる。

【0017】また、θの下限値は限りなく$\theta \fallingdotseq 0$°が望ましいが、図５、図９の鍛造後（二点鎖線）と加工完了後（実線）の関係にみられる様に、トラクション面４、内径面２の例で言えば取代が変化することにより、加工後のトラクション面４、内径面２と交わるメタルフロー６の角度は鍛造後に対し変化する。鍛造後の１本のメタルフロー６に着目すれば、上の各面に対しそれぞれの深さ方向（取代量相当）に一定の角度で交わるのではなく、刻々変化していることから明らかである。そして、本願発明でいう各面の接線とのなす角度θ、即ち、剥離や曲げ疲労に影響を及ぼすθの意味は、鍛造後の状態でいうのではなく、加工完了後、即ち、使用状態で定義するものである。

【0018】従って、鍛造後のメタルフロー６は所定取代によって加工完了時に本願発明でいうθ範囲になる状態になっていれば足りる。とは言え、θが０°又は限りなく０°に近い製品はディスクの性能上最も望ましいことは言うまでもないが、取代をできるだけ少なくしたい。又、取代のばらつき、面に直角に取代を除去するか、角度を以て取代を除去するなどの加工上の必要から、極端にθを０°に厳しく求めると、加工不良など製品歩留りを損ない、製造コストが上昇してしまう。

【0019】本願発明では、性能と製造コストの両方を満たすディスク及び製法を目的とする意味からθ＝２～３０°、好ましくは５～２０°とした。下限は主として性能と歩留りの向上の両方から、上限は主として上述したように剥離、曲げ疲労向上で限定した。

【0020】以上が本願発明のディスク表面に沿うメタルフローの定義である。

（イ）また、「ディスク表面に沿うメタルフロー」は、上述したトラクション面に加えて、ディスクの軸方向の長さをＡとした場合に小径端面から軸方向に少なくとも

１／３Ａの範囲に渡ってディスクの内径面に存在するのが好ましい。

【００２１】このように、「ディスク表面に沿うメタルフロー」を小径端面から軸方向に少なくとも１／３Ａの範囲に渡ってディスクの内径面に存在させるのは、内径面には図１７に示すように止め輪の周溝があったりして曲げ応力等の厳しい部分であるため、１／３Ａを越えるまでは本願発明のθ範囲にすることがディスクの長寿命化のために必要だからである。

（ロ）この場合、「ディスク表面に沿うメタルフロー」がディスクの小径端部側の端面にも存在するようにすると、曲げ疲労や周溝に対する応力集中を緩和することができるので、ディスクの更なる長寿命化を図ることが可能になる。

（ハ）更に、図１４を参照して、トラクション面の曲率中心Ｏを通る水平線（ディスクの軸線と平行な線）とのなす角度αが４５°以上、好ましくは４８°以上の範囲に渡って「ディスク表面に沿うメタルフロー」がトラクション面に周方向に沿って存在するようにするのが好ましい。

【００２２】このようにすると、トラクション面のうちで最も厳しい曲げ応力等を受ける領域（図１７の細かいハッチング部分参照）を「ディスク表面に沿うメタルフロー」でカバーすることが可能になって、曲げ応力等に起因するディスクの破損を防止することができる。

（ニ）更に、本発明に係るトロイダル型無段変速機のディスクは、型を用いた鍛造（後述する。）によって製作されるが、この場合、図１０及び図１５を参照して、パワーローラが水平（ディスクの軸線と平行）になったとき、即ち、変速比が１：１のときのトラクション面とパワーローラとの接触楕円の短半径をｂとした場合に、トラクション面から深さ方向に１．５ｂ以上離れた領域に高密度の非金属介在物が存在するようにするのが好ましい。

【００２３】トラクション面のうちで最も厳しいせん断応力を受ける領域はトラクション面から深さ方向に１．５ｂ未満の領域であり、この領域に介在物が存在しなければ、ディスクの寿命に影響しないからである（図１１参照）。

（ホ）また、上述したように、小径端部側の端面から軸方向に１／３Ａの範囲の内径面は止め輪の周溝があったりして曲げ応力等の厳しい部分であるため、該内径面の１／３Ａ以下の部分についても介在物が存在しないようにするのが好ましい。

【００２４】ところで、図１８及び図１９は特開９－１２６２８９号公報に開示されているトロイダル型無段変速機のディスクの製造方法を示している。これらの製法は本発明に係るディスクにおいてθ＝０°のメタルフローを備えたディスクの製造にのみ使用することが可能であるが、θ＝０°以外のメタルフローを備えたディスクの製造には適応しない他、種々の問題を有している。

【００２５】まず、図１８に示す従来のディスクの製法から説明すると、この製法は、外周面に軸方向に沿ってメタルフローｍが延在する円柱素材（浸炭鋼等）ｎを上型ｏと下型ｐとの間に同心に挟み込んで所定量成形する（図１８（ｂ）参照）。上型ｏはディスクq_1の小径端部ｒを成形する小径端部成形面ｓと断面円弧凹状のトラクション面ｔを成形するトラクション面成形面ｕとを有し、下型ｐは大径端部ｖを成形する大径端部成形面ｗを有する。そして、上型ｏ及び下型ｐを更に接近させて素材ｎを軸線方向に数回圧鍛し、これにより、素材ｎの上下端部にそれぞれ小径端部ｒ及び大径端部ｖを成形するとともに、小径端部ｒと大径端部ｖとの間にトラクション面ｔを成形する。

【００２６】次いで、図１８（ｃ）に示すように、上型ｏ及び下型ｐを最接近させて素材ｎをディスクq_1の最終形状に型鍛造し、これに研削仕上げを施すとともに内径面ｘを削り出し、これにより、図１８（ｄ）に示すようなディスクq_1の最終製品を完成させる。

【００２７】しかしながら、かかる従来の製法においては、一種類の上下型ｏ，ｐで円柱素材ｎをディスクq_1の最終形状まで鍛造するようにしてため、上下型ｏ，ｐと素材ｎとの接触時間が長くなって上下型ｏ，ｐが加工時の熱影響を被りやすくなり、この結果、上下型ｏ，ｐの表面硬度が低下して型寿命が短くなるという不都合がある。

【００２８】また、成形の最終段階で上下型ｏ，ｐの空間に密閉状態で素材ｎが充満するようになるため、上下型ｏ，ｐの角部に欠肉やバリが発生し易くなり、しかも、無理にディスクq_1の形状を良くしようとすると過大な成形荷重を要することになって上下型ｏ，ｐが破損してしまうという不都合がある。

【００２９】更に、型鍛造後の工程で研削仕上げを行うようにしているので、研削に要する加工時間の短縮を図るべく研削取りしろを小さく押さえる必要があり、この結果、鍛造時の上下型ｏ，ｐの摩耗を小さくせざるを得ず、上下型ｏ，ｐの寿命が短くなるという不都合がある。

【００３０】更に、円柱素材ｎを上下型ｏ，ｐ内で保持する構造になっていないため、円柱素材ｎが上下型ｏ，ｐの中心からずれ易くなり、この結果、加工精度が悪くなるという不都合がある。

【００３１】そこで、かかる不都合を解消するために本発明者等は次に示す従来にない新たなディスクの製造方法を考案した。この製法は本発明に係るディスクの製造、特に、本発明に加えて上述した（イ）及び（ハ）の各手段を備えたディスクの製造に好適なものである。

【００３２】即ち、このディスクの製法は、外周面に軸方向に沿ってメタルフローが延在する円柱素材を第１の鍛造型を用いて据え込む第１工程と、据え込み後の素材

を第２の鍛造型を用いて成形して前記素材の上端面中央部に内径面の一部を形成するとともに、該第２の鍛造型の成形面を転写する第２工程と、該第２工程によって得られた素材を第３の鍛造型を用いて成形して小径端部、トラクション面及び大径端部を形成するとともに第２工程で成形された内径面の一部を大径端部の背面との間に残壁が残る程度に更に押し込み、更に、該大径端部の外径面にバリを形成する第３工程とを備え、各工程を経て得られた型鍛造品の前記バリ及び前記残壁を除去した後、切削加工を施して最終形状のディスクに成形し、これに熱処理及び仕上加工を施すことを特徴とする。

【００３３】かかるディスクの製法においては、型鍛造を３工程に分けて三種類の型で行っているので、型と素材との接触時間が短くなって成形時に型に及ぼす熱影響を少なくすることができ、この結果、型表面硬度を良好に維持することが可能になって型寿命の向上を図ることができる。

【００３４】また、第１工程において円形素材の据え込み量を多くすることにより、第２工程及び製品の最終形状に近い形状を得るために高い成形荷重が必要となる第３工程での成形量を短くすることができ、この結果、第２工程及び第３工程での鍛造型の加工負担を軽減することができ、型寿命の延長を図ることができる。

【００３５】更に、第１工程において円形素材の据え込み量を多くすることにより、第２工程における鍛造型の内径面の一部を成形する部分の押し込み程度及び第３工程において鍛造型の第２工程で成形された内径面の一部を更に押し込む部分の押し込み程度を軽減することができ、この結果、鍛造型の材料の熱影響を最も受けやすい部分の寿命を飛躍的に向上させることができる。

【００３６】更に、型鍛造を３工程に分けて三種類の型で行っているので、鍛造時の材料流動を自由に設定することができ、この結果、最終形状に見合った形状を前工程（第１及び第２工程）で設定することにより、バランスの取れた型鍛造品を作ることができる。

【００３７】更に、型鍛造品に切削加工を施してディスクを得るようにしているので、切削前の鍛造品がラフな鍛造品（例えば熱間鍛造など）でも十分に対応することができ、しかも、型の摩耗をあまり気にする必要が無いため（型の摩耗が進んでも使用できるため）結果的に型費用を安くすることができる。

【００３８】更に、第３工程では成形完了時に大径端部の外径面にバリが発生するようにしているため、密閉鍛造を回避して不必要な成形荷重の増加を押さえることができ、この結果、型寿命の向上を図ることができる。

【００３９】なお、第１工程における据え込み後の素材の中央部の高さＨ１を第３工程における鍛造品完成時の素材の高さＨ２の８０～１２０％に設定すると、第２及び第３工程における鍛造型の寿命向上を効果的に達成することができる。

【００４０】また、上述した第１工程から第３工程において、各鍛造型毎に素材との芯だし位置決めを行う位置決め手段を設けることにより、各工程で素材が型の成形中心に正確且つ確実に位置決めされるようになるので、素材が常に正しい位置で成形されて精度の良い型鍛造品を得ることができる。そして、本願発明のディスクの表面に沿うメタルフローを後の加工によって得る鍛造品が得られる。

【００４１】次に、図１９に示す従来のディスクの製法を説明する。この製法は、ディスクq_2の内径面ｘの一部を型鍛造時に成形するようにしたものであり、まず、図１９（ｂ）に示すように、円柱素材ｎの上端部に絞り加工を施して該上端部の径を小径端部ｒの径より小径にし、次いで、円柱素材ｎを上型ｙと下型ｚとの間に同心に挟み込んで所定量成形する（図１９（ｃ）参照）。上型ｙはディスクq_2の小径端部ｒを成形する小径端部成形面ｓと断面円弧凹状のトラクション面ｔを成形するトラクション面成形面ｕと小径端部成形面ｓの中心部に設けられて小径端部ｒ側から内径面ｘの一部を成形する突起a_1とを有し、下型ｚは大径端部ｖを成形する大径端部成形面ｗと大径端部成形面ｗの中心部に設けられて大径端部ｖ側から内径面ｘの一部を成形する突起a_2とを有する。

【００４２】次いで、上型ｙ及び下型ｚを更に接近させて素材ｎを軸線方向に数回圧鍛し、これにより、素材ｎの上下端部にそれぞれ小径端部ｒ及び大径端部ｖを成形するとともに、小径端部ｒと大径端部ｖとの間にトラクション面ｔを成形し、更に、突起a_1，a_2による内径面ｘの成形を開始する。

【００４３】次に、図１９（ｄ）に示すように、上型ｙ及び下型ｚを最接近させて素材ｎをディスクq_2の最終形状に型鍛造する。このとき、内径面ｘは残壁a_3を残した状態になっている。次いで、ここまで成形された素材ｎを上型ｙ及び下型ｚから取り出し、その後、内径面ｘの残壁a_3を削り出し又は研削により除去して内径面ｘを完成させるとともに、素材ｎに更に研削仕上げを施すことにより、ディスクq_2の最終製品を完成させる。

【００４４】かかる従来のディスクの製法においては、図１９（ｂ）で円柱素材ｎの上下端面に現れていたメタルフローｍの端点が同図（ｃ）で内部に引き込まれて縮小する現象が示され、これにより、トラクション面ｔから小径端部ｒ及び該小径端部ｒ側の内径面ｘにかけて、メタルフローｍがディスクq_2の表面形状に沿って存在（$\theta=0°$）する様子が示されている。

【００４５】しかしながら、図１９（ｃ）の工程において、メタルフローｍの端点を円柱素材ｎの内部に引き込むように成形するのは非常に難しく、従って、メタルフローｍの端点が素材ｎの上下端面のどこかの表面に残ってしまうことが多い。この結果、$\theta=0°$のメタルフローｍをディスクq_2の表面に沿って確実に存在させるこ

とが困難であるという不都合がある。

【0046】また、円柱素材nの中心部近傍に存在する高密度の非金属介在物が、曲げ応力の厳しい部分であるディスクq_2の小径端面から軸方向に1／3Aの範囲の内径面に残存する可能性が大きく、ディスク寿命に悪影響を及ぼすという不都合がある。

【0047】そこで、かかる不都合を解消するために本発明者等は次に示す従来にない新たなディスクの製造方法を考案した。この製法は本発明に係るディスクの製造、特に、本発明に加えて上述した（イ）～（ホ）の全ての手段を備えたディスクの製造に好適なものである。

【0048】即ち、このディスクの製法は、第1の鍛造型を用いて外周面に軸方向に沿ってメタルフローが延在する円柱素材を据え込むとともに該円柱素材の上端部に絞りを付与する第1工程と、第2の鍛造型を用いて第1工程によって得られた素材を成形して小径端部、トラクション面及び大径端部を形成するとともに、前記素材の中央部に前記大径端部の背面との間に残壁を残した状態で内径面の一部を形成する第2工程とを備え、第2工程において前記素材の中央部に前記内径面の一部を形成するに際し、前記第2の鍛造型の一部で該素材の上端部を拘束して該上端部が成形中に拡径しないようにするとともに、前記素材の中心部に存在する高密度の非金属介在物を該素材の下端側に押し込んで該下端側で径方向外方に膨出させ、更に、各工程を経て得られた型鍛造品の前記残壁を除去した後、切削加工を施して最終形状のディスクに成形し、これに熱処理及び仕上加工を施すことを特徴とする。

【0049】かかるディスクの製法においては、小径端部側の端面、トラクション面、大径端部の外周面及び該大径端部の背面にそれぞれθ＝2～30°の「ディスク表面に沿うメタルフロー」が存在するディスク（完成品）を簡単且つ確実に得ることができる。

【0050】また、型鍛造であるため第1工程における円柱素材の径を小さくでき、しかも、第2工程において素材の上端部を拘束して該上端部が成形中に拡径しないようにするとともに、素材の中心部に存在する高密度の非金属介在物を該素材の下端側に押し込んで該下端側で径方向外方に膨出させるようにしているため、トラクション面のうちで最も厳しいせん断応力を受ける部分であるトラクション面から深さ方向に1．5b未満の領域、及び内径面のうちで止め輪の周溝があったりして曲げ応力等の厳しい部分である小径端部側の端面から軸方向に1／3A（Aはディスクの軸長）の範囲を越えるまでの領域に高密度の非金属介在物が存在しないディスクを簡単且つ確実に得ることができる。

【0051】なお、この第2工程では成形完了時に大径端部の外径面にバリが発生するように成形するのが好ましく、このバリを発生させることにより、密閉鍛造を回避して不必要な成形荷重の増加を押さえることができ、

この結果、型寿命の向上を図ることができる。

【0052】また、上述した第1工程及び第2工程において、各鍛造型毎に素材との芯だし位置決めを行う位置決め手段を設けることにより、各工程で素材が型の成形中心に正確且つ確実に位置決めされるようになるので、素材が常に正しい位置で成形されて精度の良い型鍛造品を得ることができる。

【0053】

【発明の実施の形態】以下、本発明の実施の形態を図を参照して説明する。図1は本発明の第1の実施の形態であるトロイダル型無段変速機の入力及び出力ディスクを説明するための説明図、図2はディスクの製法の第1工程を説明するための説明図、図3はディスクの製法の第2工程を説明するための説明図、図4はディスクの製法の第3工程を説明するための説明図、図5はディスクの製法の最終工程の一例を説明するための説明図、図6は本発明の第2の実施の形態であるトロイダル型無段変速機の入力及び出力ディスクを説明するための説明図、図7はディスクの製法の第1工程を説明するための説明図、図8はディスクの製法の第2工程を説明するための説明図、図9はディスクの製法の最終工程の一例を説明するための説明図である。

【0054】まず、図1を参照して、本発明の第1の実施の形態であるディスク（完成品）から説明すると、このディスク1は小径端部2と大径端部3との間に断面円弧凹状のトラクション面4が形成されており、小径端部2側の端面中心部には大径端部3の背面まで貫通する穴が形成されて該穴の内周面が内径面5とされている。ここで、図1及び図14を参照して、ディスク1に存在するメタルフロー6のうちで、トラクション面4側のメタルフロー6と該トラクション面4の接線Pとのなす角度θが2～30°、好ましくは5～20°になるような位置関係をディスク1の表面に対して有するメタルフロー6を「ディスク表面に沿うメタルフロー6」と定義する。

【0055】このディスク1においては、トラクション面4にθ＝2～30°の「ディスク表面に沿うメタルフロー6」が存在し、内径面5にθ＝2～30°の「ディスク表面に沿うメタルフロー6」がディスク1の軸方向の長さをAとした場合に小径端部2側の端面から軸方向に1／3Aの範囲に渡って存在し、大径端部3の外径面及び該大径端部3の背面の一部にθ＝2～30°の「ディスク表面に沿うメタルフロー6」が存在している。

【0056】また、トラクション面4には、θ＝2～30°の「ディスク表面に沿うメタルフロー6」が、図14を参照して、トラクション面4の曲率中心Oを通る水平線（ディスクの軸線と平行な線）とのなす角度αが45°の範囲で周方向に沿って存在している。なお、トラクション面4の接線Pとのなす角度θが30°を越えるメタルフロー6は、エンドフロー（ディスク表面に沿わ

ないメタルフロー）と同等となって材料の剥離を発生させるとともに、曲げ疲労等によるディスクの破壊（割れ寿命低下）を招く原因になる。
【0057】かかる構成のディスク1においては、パワーローラが大きな圧力で摩擦係合するトラクション面4にθ＝2～30°の「ディスク表面に沿うメタルフロー6」が存在しているため、特に低負荷仕様の場合において、トラクション面4のパワーローラの摩擦係合部分における材料の剥離を防止することができるとともに、ディスク1に衝撃割れや疲労割れが発生し難くなってディスク1の長寿命化を図ることができる。
【0058】また、ディスク1の内径面5にθ＝2～30°の「ディスク表面に沿うメタルフロー6」が小径端部2側の端面から軸方向に1／3Aの範囲に渡って存在しているので、内径面5のうちで止め輪の周溝があったりして曲げ応力等の厳しい部分を越えるまではエンドフローが出ないようにすることができ、この結果、ディスク1の更なる長寿命化を図ることができる。
【0059】更に、トラクション面4には、θ＝2～30°の「ディスク表面に沿うメタルフロー6」が、α＝45°の範囲で周方向に沿って存在しているため、トラクション面4のうちで最も厳しい曲げ応力等を受ける領域（図17の細かいハッチング部分参照）が「ディスク表面に沿うメタルフロー6」でカバーされて曲げ応力等に起因するディスク1の破損を良好に防止することができる。
【0060】次に、ディスク1の製造方法を図2～図5を参照して説明する。
（第1工程）図2に第1工程（据え込み工程）を示す。図2の左半分は据え込み前の状態、右半分は据え込み後の状態を表している。この第1工程では、上型11と下型12との間に外周面に軸方向に沿ってメタルフロー6が延在する円柱状材（浸炭鋼等）W_1 を配置し、次いで、上型11を円柱素材W_1 の軸線方向に移動させて該円柱素材W_1 を据え込み、右半分に示すような形状の素材W_2 に成形する。ここで、この工程では据え込み比率を通常より大きくしており、この場合、据え込み後の素材W_2 の中央部の高さH1を図4に示す鍛造完成時の素材W_4 の高さH2の80～120％に設定すると、後述する第2及び第3工程における鍛造型の寿命向上に効果的である。
【0061】下型12の平面部12aには円柱素材W_1 の下端部が嵌まり込む凹部13が設けられており、これにより、円柱素材W_1 の正確な芯出しが確保されるようになっている。また、上型11の中央部には円柱素材W_1 の径より小径の円形凸部14が設けられており、該円形凸部14は据え込み時に円柱素材W_1 の中央部を成形して材料を拡径するように作用する。更に、上型11の円形凸部14の外周側の平面部11aと該円形凸部14との間には円形凸部14から径方向外方に向けて次第に上方に膨らむように湾曲して平面部11aに連なる湾曲成形面15が設けられており、該湾曲成形面15は据え込まれた素材W_2 に湾曲形状を転写するようになっている。
（第2工程：中押し工程）図3は第2工程を示す図であり、左半分が成形前の状態を示し、右半分が成形後の状態を示している。第2工程の役割は、第3工程で欠肉やバリが発生するのを防ぐボリューム配分を行うために素材に最適な形状を与えることである。第2工程での素材形状が不適正であると、第3工程で素材を成形した際、素材の内径面角部（上端側）にバリや欠肉を生じたり、素材の大径端部の外径面のバリ（後述する。）に欠肉を生じたりする。また、第2工程のもう一つの役目は、第3工程での素材W_3 と型との芯出しを確実に行える形状を付与することにある。
【0062】まず、上下型21，22について説明すると、上型21の平面部21aの中央部には略円錐状突起からなる中型25が突設されている。一方、下型22は、外周寄りの部分に第1工程で据え込まれた素材W_2 の径方向外側に斜め上方に傾斜する傾斜部23が設けられており、素材W_2 の下端側外周縁と傾斜部23が接触したところで該素材W_2 と下型22の芯が一致するようになっている。このとき、素材W_2 の下端面は下型22の中央平面部22aに突設された凸部24の上端面からわずかに浮いた状態になっている。
【0063】そして、この状態で上型21及び中型25を一体に下降させると、中型25が素材W_2 の上端面中央部に侵攻して内径面5の一部である凹部5aを形成するとともに、上型21の平面部21aが素材W_2 の上端面を押圧して成形圧力を付与し、この成形圧により素材W_2 は、図3の右半分に示すように、その下端部において、下型22の平面部22a、傾斜部23及び凸部24の形状が転写されて素材W_3 の形状に成形される。
（第3工程）図4は第3工程を示す図であり、左半分は成形前の状態、右半分は成形後の状態を表している。上型31はディスク1の小径端部2を成形する小径端部成形面33と断面円弧凹状のトラクション面4を成形するトラクション面成形面34と小径端部成形面33の中心部に設けられて小径端部2側から内径面5の一部を成形する中型35とを有し、下型32は大径端部3を成形する大径端部成形面36と大径端部成形面36の中心部に中型35と同心に設けられた凸部37とを有する。凸部37には上述した第2工程で下型22の凸部24の形状が転写された素材W_3 の凹部26が嵌め込まれるようになっており、これにより、素材W_3 が下型32の中央部に正確且つ確実に位置決めされるようになっている。また、下型32の外周部には外型38が配置されており、該外型38と下型32とによって凹状の大径端部成形空間が形成されている。
【0064】そして、この状態で、上型31及び中型3

５を一体に下降させると、素材W_3に小径端部成形面３３、トラクション面成形面３４及び大径端部成形面３５がそれぞれ転写されとるともに、中型３５が素材W_3 の凹部５ａに侵攻して下端側の凹部２６との間に残壁３９を残した状態で内径面５の一部である凹部５ｂを成形し、これにより、図４の右半分に示すように、ディスク１の最終形状に近い形状の素材W_4 に成形される。なお、第３工程では成形完了時に上型３１と外型３８との間にすき間Cを形成して大径端部３の外径面にバリＳが発生するようにしており、このバリＳを発生させることにより、密閉鍛造を回避して不必要な成形荷重の増加を押さえ、型寿命の向上を図っている。

【００６５】このようにして得られた型鍛造品W_4 は後工程にて、図５の二点鎖線で示す状態からバリＳをプレスにてトリミング除去するとともに、内径面５の残壁３９をプレスにて目抜し、その後、全面に切削加工を施すことにより、図５の実線で示す最終形状のディスク１に成形される。そして、かかる成形後、ディスク１に浸炭または浸炭窒化処理により熱処理を行い、さらに研削により必要精度を付与した後、トロイダル型無段変速機のディスクとして組み込まれる。

【００６６】かかるディスクの製法においては、型鍛造を３工程に分けて三種類の型を用いて行っているので、型と素材との接触時間が短くなって成形時に型に及ぼす熱影響を少なくすることができ、この結果、型表面硬度を良好に維持することが可能になって型寿命の向上を図ることができる。

【００６７】また、第１工程において円形素材W_1 の据え込み量を多くしているので、第２工程及び製品形状に近い状態を得るために高い成形荷重が必要となる第３工程での成形量を短くすることができ、この結果、第２工程での鍛造型２１，２２及び第３工程での鍛造型３１，３２の加工負担を軽減することができ、型寿命の延長を図ることができる。

【００６８】更に、第１工程において円形素材W_1 の据え込み量を多くしていることから、第２工程での中型２５の押し込み程度及び第３工程での中型３５の押し込み程度を軽減することができ、この結果、材料の熱影響を最も受けやすい中型２５，３５の工具寿命を飛躍的に向上させることができる。

【００６９】更に、第１工程から第３工程の各工程で素材が型の成形中心に正確且つ確実に位置決めされるようになっているので、素材が常に正しい位置で成形されて精度の良い型鍛造品を得ることができる。

【００７０】更に、型鍛造を３工程に分けて三種類の型を用いて行っているので、鍛造時の材料流動を自由に設定することができ、この結果、最終形状に見合った形状を前工程（第１及び第２工程）で設定することにより、バランスの取れた型鍛造品を作ることができる。

【００７１】更に、型鍛造品W_4 に切削加工を施してディスク１を得るようにしているので、切削前の鍛造品がラフな鍛造品（例えば熱間鍛造など）でも十分に対応することができ、しかも、型の摩耗をあまり気にする必要が無いため（型の摩耗が進んでも使用できるため）結果的に型費用を安くすることができる。

【００７２】次に、本発明の第２の実施の形態であるトロイダル型無段変速機のディスクを説明する。図６に示すように、このディスク（完成品）５１は小径端部２と大径端部３との間に断面円弧凹状のトラクション面４が形成されており、小径端部２側の端面中心部には大径端部３の背面まで貫通する穴が形成されて該穴の内周面が内径面５とされている。ここで、図６及び図１４を参照して、ディスク５１に存在するメタルフロー６のうちで、トラクション面４側のメタルフロー６と該トラクション面４の接線Ｐとのなす角度θが２～３０°、好ましくは５～２０°になるような位置関係をディスク５１の表面に対して有するメタルフロー６を「ディスク表面に沿うメタルフロー６」と定義すると、このディスク５１においては、小径端部２側の端面、トラクション面４、大径端部３の外径面及び該大径端部３の背面にそれぞれθ＝２～３０°の「ディスク表面に沿うメタルフロー６」が連続して存在し、内径面５にθ＝２～３０°の「ディスク表面に沿うメタルフロー６」がディスク５１の軸方向の長さをＡとした場合に小径端部２側の端面から軸方向に１／３Ａの範囲に渡って存在している。

【００７３】なお、トラクション面４の接線Ｐとのなす角度θが３０°を越えるメタルフロー６は、エンドフロー（ディスク表面に沿わないメタルフロー）と同等となって材料の剥離を発生させるとともに、曲げ疲労等によるディスクの破壊（割れ寿命低下）を招く原因になる。

【００７４】また、このディスク５１は、図１０及び図１５を参照して、パワーローラが水平（ディスクの軸線と平行）になったとき、即ち、変速比が１：１のときのトラクション面とパワーローラとの接触楕円の短半径をｂとした場合に、トラクション面４から深さ方向に１．５ｂ以上離れた領域に高密度の非金属介在物５２が存在するようになっており、更には、内径面５の小径端部２側の端面から軸方向に１／３Ａ（Ａはディスク５１の軸長）以下の部分については高密度の非金属介在物５２が存在しないようになっている。

【００７５】かかる構成のディスク５１においては、パワーローラが大きな圧力で摩擦係合するトラクション面４にθ＝２～３０°の「ディスク表面に沿うメタルフロー６」が該トラクション面４に沿って連続して存在しているため、特に高負荷仕様の場合において、トラクション面４のパワーローラの摩擦係合部分における材料の剥離を防止することができるとともに、ディスク５１に衝撃割れや疲労割れが発生し難くなってディスク５１の長寿命化を図ることができる。

【００７６】また、ディスク１の内径面５にθ＝２～３

0°の「ディスク表面に沿うメタルフロー６」が小径端部２側の端面から軸方向に１／３Ａの範囲に渡って存在しているので、内径面５のうちで止め輪の周溝があったりして曲げ応力等の厳しい部分を越えるまではエンドフローが出ないようにすることができるとともに、θ＝２～３０°の「ディスク表面に沿うメタルフロー６」がディスク５１の小径端部２側の端面にも存在しているので、曲げ疲労や周溝に対する応力集中を緩和することができ、この結果、ディスク５１の更なる長寿命化を図ることができる。

【００７７】更に、トラクション面４のうちで最も厳しいせん断応力を受ける部分であるトラクション面４から深さ方向に１．５ｂ未満の領域、及び内径面５のうちで止め輪の周溝があったりして曲げ応力等の厳しい部分である小径端部２側の端面から軸方向に１／３Ａ以下の範囲を越えるまでの領域に高密度の非金属介在物５２が存在しないようになっているため、介在物によるディスク５１の寿命への悪影響を回避することができる。

【００７８】次に、ディスク５１の製造方法を図７～図９を参照して説明する。

（第１工程：据え込み工程）図７は第１工程（据え込み工程）を示しており、左半分は据え込み前の状態、右半分は据え込み後の状態を表している。この第１工程では、上型５１と下型５２との間に、外周面に軸方向に沿ってメタルフロー６が延在する円柱素材（浸炭鋼等）W_{11}を配置し、上型５１を円柱素材W_{11}の軸線方向に移動させて該円柱素材W_{11}を据え込み、右半分に示すような形状の素材W_{12}に成形する。

【００７９】下型５２の平面部５２ａの中央部には円柱素材W_{11}の下端部が嵌まり込む凹部５３が設けられており、凹部５３に円柱素材W_{11}の下端部が嵌まり込むことにより、下型２との芯出しが正確且つ確実に行われるようになっている。

【００８０】一方、上型５１の中央部には上方に向けて縮径するテーパ凹部５１ａが凹部５３と同心に設けられており、該テーパ凹部５１ａの底面は平坦面５４とされている。テーパ凹部５１ａの斜面部５５には円柱素材W_{11}の上端面の周縁（外周面と上端面との境部）が当接しており、これにより、上型５１が下降する際に円柱素材W_{11}の上端部を規制して上型５１との芯出しを正確且つ確実に行いつつ斜面部５５の形状を転写するようになっている。

（第２工程）図８は第２工程を示しており、左半分が成形前の状態、右半分が成形後の状態を表している。この第２工程では、下型６２と外型６５に取り付けられた上型６１との間に第１工程で据え込まれた素材W_{12}を配置し、上型６１を素材W_{12}の軸線方向に移動させて右半分に示すようなディスク５１の最終形状に近い形状の素材W_{13}に成形する。

【００８１】下型６２はディスク５１の大径端部３を成形する大径端部成形面６３を有しており、該大径端部成形面６３の中央部には第１工程での素材W_{12}の下端部において下型５２の凹部５３の形状が転写された凸部５６が嵌まり込む凹部６４が設けられており、素材W_{12}の凸部５６が下型６２の凹部６４に嵌まり込むことにより、下型６２に対しての素材W_{12}のがたつきが防止されて下型６２との芯出しが正確且つ確実に行われるようになっている。

【００８２】外型６５はディスク５１の小径端部２を成形する小径端部成形面６６とトラクション面４を成形するトラクション面成形面６７とを有しており、小径端部成形面６６の中央部には円柱状の上型６１が突設されている。

【００８３】上型６１の下端面には、上方に向けて次第に縮径する浅いテーパ凹部６８が形成されている。テーパ凹部６８の底面は平坦面６９とされており、該平坦面６９の径は第１工程で据え込まれた素材W_{12}の上端面において中心部に存在する高密度の非金属介在物５２の領域径より大径とされている。また、テーパ凹部６８の斜面部７０には素材W_{12}の上端部外周面が当接して上型６１との芯出しが正確且つ確実に行われるようになっている。従って、テーパ凹部６８の斜面部７０の素材W_{12}の当接位置における内径D_2は素材W_{12}の上端面の径D_1より大径になっている。

【００８４】そして、この状態で、外型６５及び上型６１を一体に下降させると、素材W_{12}に小径端部成形面６６、トラクション面成形面６７及び大径端部成形面６３がそれぞれ転写されとるとともに、上型６１が素材W_{12}の中央部に侵攻して凹部６４との間に残壁７１を残した状態で内径面５の一部である凹部５ｄが成形され、これにより、図８の右半分に示すように、ディスク５１の最終形状に近い形状の素材W_{13}に成形される。なお、この第２工程では成形完了時に下型６２と外型６５との間にすき間Ｃを形成して大径端部３の外径面にバリＳが発生するようにしており、このバリＳを発生させることにより、密閉鍛造を回避して不必要な成形荷重の増加を押さえ、型寿命の向上を図っている。

【００８５】また、上型６１が素材W_{12}の中央部を侵攻する際には、上型６１のテーパ凹部６８が素材W_{12}の上端部を拘束して該上端部が成形中に拡径しないようにするとともに、素材W_{12}の中心部に存在する高密度の非金属介在物５２を該素材W_{12}の下端側に押し込んで該下端側で径方向外方に膨出させるようになっている。

【００８６】このようにして得られた型鍛造品W_{13}は後工程にて、図９の二点鎖線で示す状態からバリＳをプレスにてトリミング除去するとともに、内径面５の残壁７１をプレスにて目抜し、その後、全面に切削加工を施すことにより、図９の実線で示す最終形状のディスク５１に成形される。そして、かかる成形後、ディスク５１に浸炭または浸炭窒化処理により熱処理を行い、さらに研

削により必要精度を付与した後、トロイダル型無段変速機のディスクとして組み込まれる。

【0087】上記記載から明らかなように、かかるディスクの製法においては、小径端部2側の端面、トラクション面4、大径端部3の外周面及び該大径端部3の背面にそれぞれθ＝2～30°の「ディスク表面に沿うメタルフロー6」が存在するディスク（完成品）51を簡単且つ確実に得ることができる。

【0088】また、型鍛造であるため第1工程における円柱素材W_{11}の径を小さくでき、しかも、第2工程において上型61のテーパ凹部68が素材W_{12}の上端部を拘束して該上端部が成形中に拡径しないようにするとともに、素材W_{12}の中心部に存在する高密度の非金属介在物52を該素材W_{12}の下端側に押し込んで該下端側で径方向外方に膨出させるようにしているため、トラクション面4のうちで最も厳しいせん断応力を受ける部分であるトラクション面4から深さ方向に1．5ｂ未満の領域、及び内径面5のうちで止め輪の周溝があったりして曲げ応力等の厳しい部分である小径端部2側の端面から軸方向に1／3Ａの範囲を越えるまでの領域に高密度の非金属介在物52が存在しないディスク51を簡単且つ確実に得ることができる。

【0089】

【実施例】表1に荷重5ｔ、荷重位置がトラクション面の溝底とした場合に、α（図参照）を相違させて各ディ＊スクの耐久性試験を行った結果を示す。ここで、αは、図14を参照して、トラクション面4の曲率中心Oを通る水平線（ディスクの軸線と平行な線）とのなす角度である。

【0090】表1のNO．1～NO．6のディスクまでは本発明の実施例であり、NO．1～NO．4のディスクはトラクション面にθ＝2～30°の「ディスク表面に沿うメタルフロー」が存在し、このうちのNO．1及びNO．2のディスクはα＜45°とし、NO．3及びNO．4のディスクはα≧45°とした。また、NO．5及びNO．6のディスクはθ＝2～30°の「ディスク表面に沿うメタルフロー」がトラクション面に連続して存在するものを用いた。更に、NO．7及びNO．8のディスクは従来例とし、削り出しによって製作したものを用いた。これらの条件以外は全て同一条件（大きさ、材質及び荷重条件等）として耐久性試験を行った。

【0091】なお、θ＝2～30°とする調整は、予め鍛造後のメタルフローを調査し、取代を調整することでα°以内は本願発明のθ範囲を満たすディスク表面に沿うメタルフローとし、α°を越える範囲を本願発明のθの範囲外のメタルフローが存在するようにして、破損を観察した。鍛造ディスクは上述した2つの製法を適宜用いて製作した。

【0092】

【表1】

No.	種類	α [deg]	実験結果	判定
1	実施例	27	123hrで破損	△
2	〃	37	194hrで破損	△
3	〃	48	289hrで振動，トラクション面にクラック	○
4	〃	50	272hrで振動，トラクション面にクラック	○
5	〃	－	350hrで異常なし	◎
6	〃	－	350hrで異常なし	◎
7	従来例	－	97hrで破損	×
8	従来例	－	63hrで破損	×

荷重：約5 ton
荷重位置：溝底

【0093】表1から明らかなように、本発明のディスク（NO．1～NO．6）は従来のディスク（NO．7及びNO．8）に比べてトラクション面の耐久性が大幅に向上しているのが判る。

【0094】また、本発明のディスクのうちでα≧45°のディスク（NO．3及びNO．4）はα＜45°のディスク（NO．1及びNO．2）に比べてより耐久性が向上しており、更に、θ＝2～30°の「ディスク表面に沿うメタルフロー」がトラクション面に連続して存在するディスク（NO．5及びNO．6）については、350時間経過してもトラクション面に異常は無く、最も耐久性に優れていることが判る。

【0095】なお、試験は350ｈｒで止めたが、θ≒0°とθ＝2°とは共に350ｈｒ以上となり、性能上※ほぼ同程度と推定される。表2にトラクション面から高密度の非金属介在物（0．3D部：図10及び図12参照）の領域までの深さを相違させて各ディスクの耐久性試験を行った結果を示す。なお、表2においてｂは変速比が1：1のときのトラクション面とパワーローラとの接触楕円の短半径である（図15参照）。

【0096】表2のNO．1～NO．8のディスクは全て本発明の実施例であり、各ディスク共、トラクション面にθ＝2～30°の「ディスク表面に沿うメタルフロー」が存在するものを用い、トラクション面から高密度の非金属介在物領域までの深さが相違する以外は全て同一条件で耐久性試験を行った。

【0097】

【表2】

No.	0.3D部の表面からの深さ	実験結果	判定
1	0	170hrにてトラクション面剥離	△
2	0.25 b	173hrにてトラクション面剥離	△
3	0.60 b	212hrにてトラクション面剥離	○
4	0.90 b	208hrにてトラクション面剥離	○
5	1.25 b	239hrにてトラクション面剥離	○
6	1.8 b	250hr異常なし	◎
7	2.55 b	250hr異常なし	◎
8	4.5 b	250hr異常なし	◎

b： 変速比が1：1のときのトラクション面とパワーローラとの接触楕円の短半径

【0098】表2から明らかなように、トラクション面から高密度の非金属介在物領域までの深さが深くなるにしたがってトラクション面の耐久性が向上しているのが判り、特に、該深さが1．5b以上になると250時間経過しても異常がなく、最も耐久性に優れていることが判る。

【0099】表3にディスク内径面の高密度の非金属介在物の存在領域が相違する各ディスクについて、小径端部側の内径面の耐久性試験を行った結果を示す。ここで、Aはディスクの軸長、Bは内径面における小径端部側の端面からの軸方向の長さを示す。

【0100】表3のNO．3～NO．8のディスクは全て本発明の実施例であり、各ディスク共、内径面にθ＝2～30°の「ディスク表面に沿うメタルフロー」がデ＊ィスクの軸長をAとした場合に小径端部側の端面から軸方向の深さ（B／A）×100％の範囲に存在する各種ディスクを用い試験した。また、NO．1及びNO．2のディスクは従来例とし、削り出しによって製作したものを用いた。これらの条件とディスク内径面の高密度の非金属介在物の存在領域が相違する以外は全て同一条件で耐久性試験を行った。なお、NO．3～NO．8のディスクにおいて、非金属介在物とその存在領域（B／A）×100％との関係は、取代を調整して製作することによって調整した。この場合も上述した2つの製法による鍛造ディスクを適宜用いた。

【0101】

【表3】

No.	種類	加工方法	(B/A)×100[%]	実験結果	判定
1	従来例	削り出し	－	68hrで小径側内径部より破損	×
2	〃	削り出し	－	59hrで小径側内径部より破損	×
3	実施例	鍛造	15	171hrで小径側内径部より破損	△
4	〃	鍛造	22	211hrで小径側内径部より破損	○
5	〃	鍛造	34	250hr問題なし	◎
6	〃	鍛造	41	250hr問題なし	◎
7	〃	鍛造	53	250hr問題なし	◎
8	〃	鍛造	51	250hr問題なし	◎

【0102】表3から明らかなように、本発明のディスク（NO．3～NO．8）は従来のディスク（NO．1及びNO．2）に比べて小径端部側の内径面の耐久性が大幅に向上しているのが判る。

【0103】また、本発明のディスクのうちで内径面において（B／A）×100％が33％を越える領域に高密度の非金属介在物が存在するものについては、250時間経過しても小径端部側の内径面に異常は無く、最も耐久性に優れていることが判る。

【0104】

【発明の効果】上記の説明から明らかなように、本発明によれば、トロイダル型無段変速機のディスクにおいて、生産コストの低減が可能になるとともに、ディスクの長寿命化を図ることができるという効果が得られる。

【図面の簡単な説明】

※【図1】本発明の第1の実施の形態であるディスクを説明するための説明図である。

【図2】ディスクの製法の第1工程を説明するための説明図であり、左半分は成形前の状態、右半分は成形後の状態を表している。

【図3】ディスクの製法の第2工程を説明するための説明図であり、左半分は成形前の状態、右半分は成形後の状態を表している。

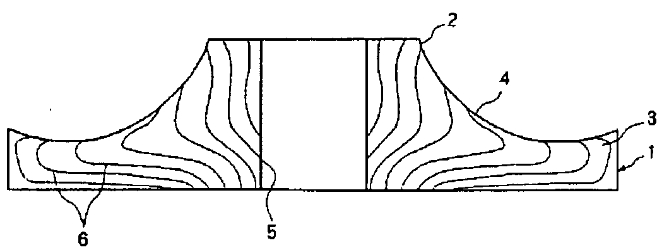
【図4】ディスクの製法の第3工程を説明するための説明図であり、左半分は成形前の状態、右半分は成形後の状態を表している。

【図5】ディスクの製法の最終工程の一例を説明するための説明図である。

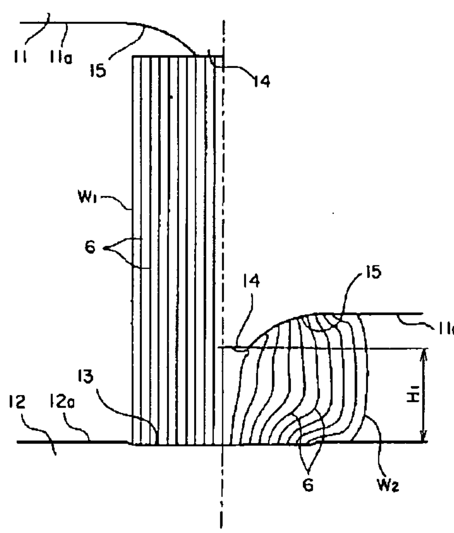
【図6】本発明の第2の実施の形態であるディスクを説明するための説明図である。

【図7】ディスクの製法の第1工程を説明するための説明図であり、左半分は成形前の状態、右半分は成形後の状態を表している。
【図8】ディスクの製法の第2工程を説明するための説明図であり、左半分は成形前の状態、右半分は成形後の状態を表している。
【図9】ディスクの製法の最終工程の一例を説明するための説明図である。
【図10】ディスクにおける高密度の非金属介在物の存在箇所を説明するための説明図である。
【図11】トラクション面の表面からの深さとせん断応力の分布との関係を説明するためのグラフ図である。
【図12】成形前の円柱素材における高密度の非金属介在物の存在箇所を説明するための説明図である。
【図13】成形前の円柱素材における直径と介在物の数との関係を説明するための説明図である。
【図14】αとθの意味を説明するための説明図である。
【図15】トロイダル型無段変速機を説明するための説明的断面図である。
【図16】従来のディスクを説明するための説明図である。
【図17】ディスクにおいて大きな繰り返し曲げ応力や繰り返しせん断応力を受ける部分を説明するための説明図である。
【図18】従来のディスクの製法を説明するための説明図である。
【図19】従来の他のディスクの製法を説明するための説明図である。
【符号の説明】
1，51…ディスク
2…小径端部
3…大径端部
4…トラクション面
6…メタルフロー
c…パワーローラ
P…接線
θ…トラクション面の接線とメタルフローとのなす角度

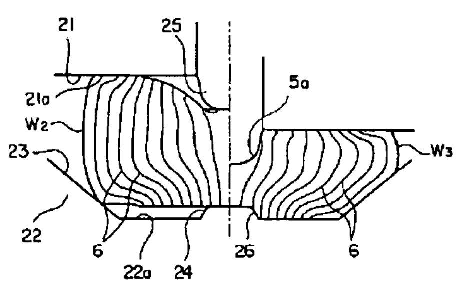
【図1】



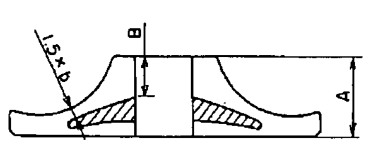
【図2】



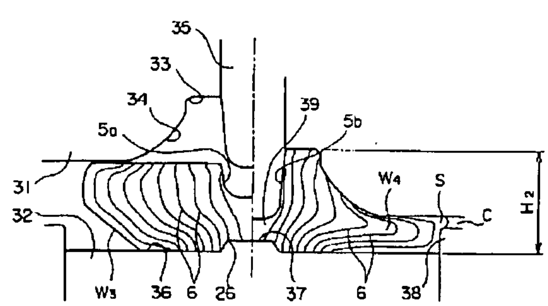
【図3】



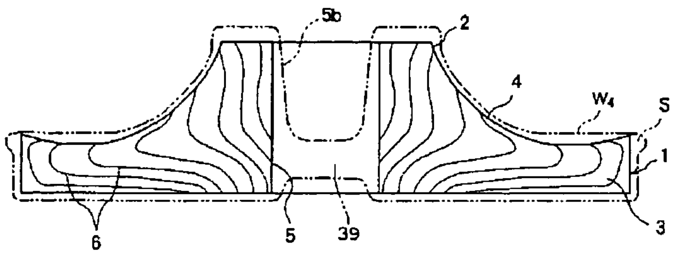
【図10】



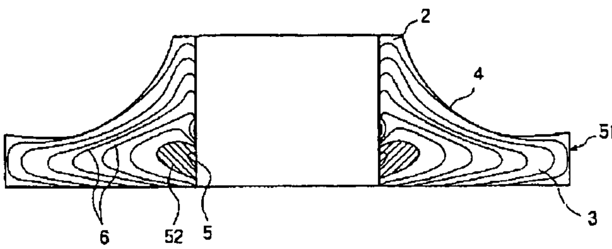
【図4】



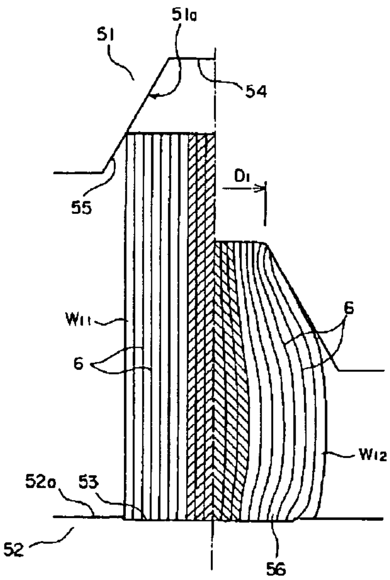
【図5】



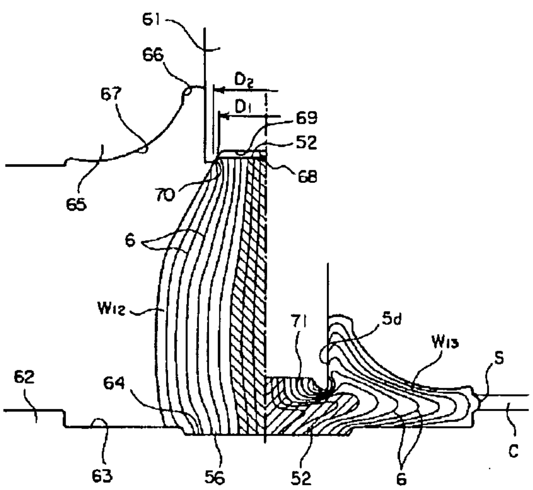
【図6】



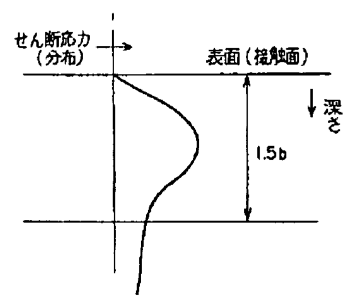
【図7】



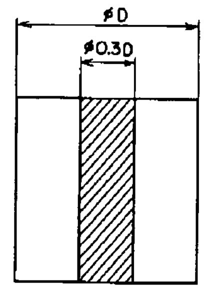
【図8】



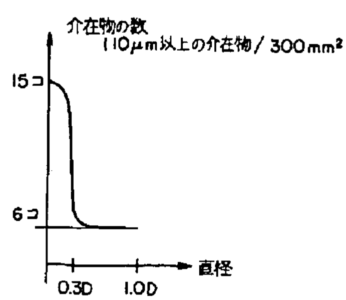
【図11】



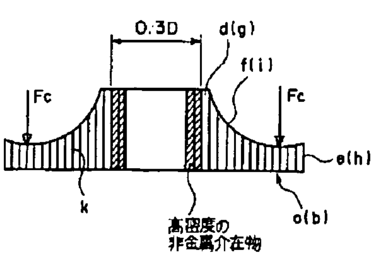
【図12】



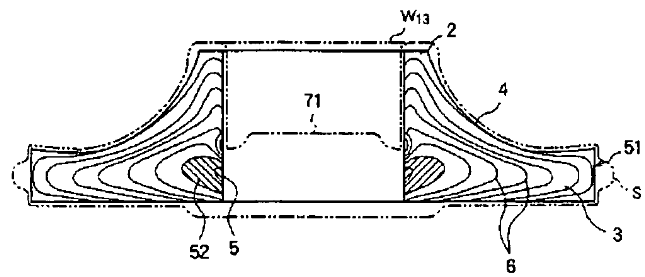
【図13】



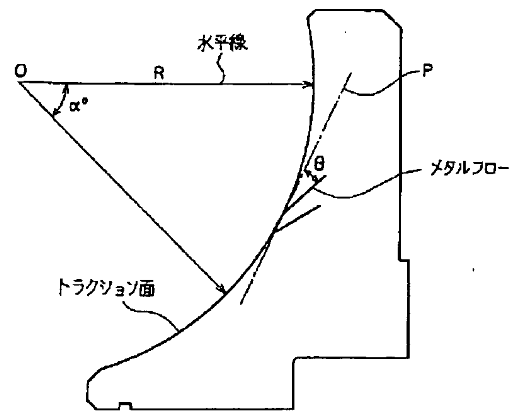
【図16】



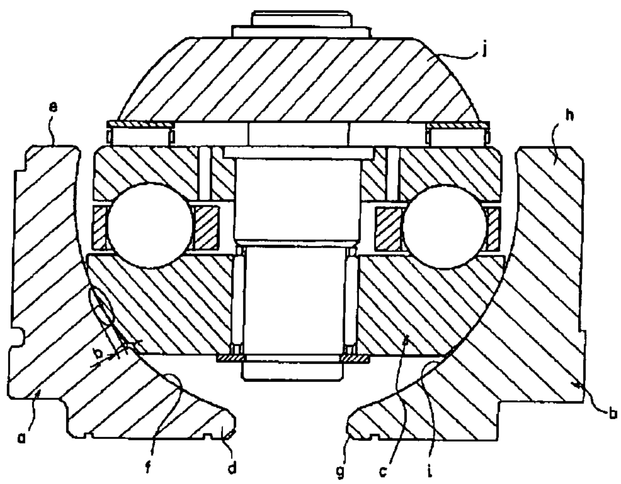
【図9】



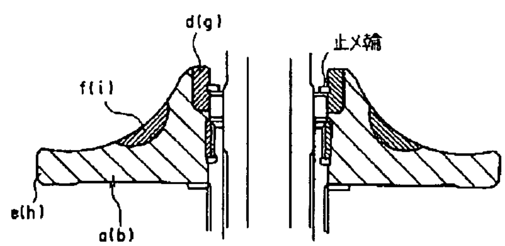
【図14】



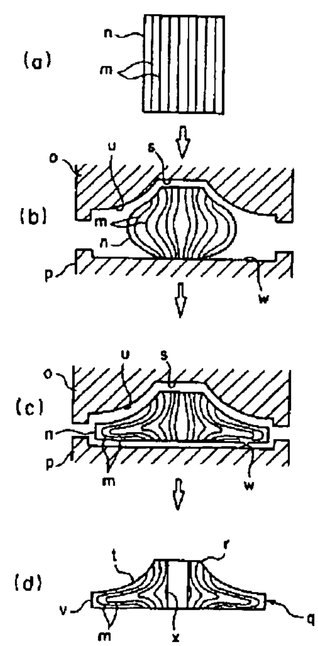
【図15】



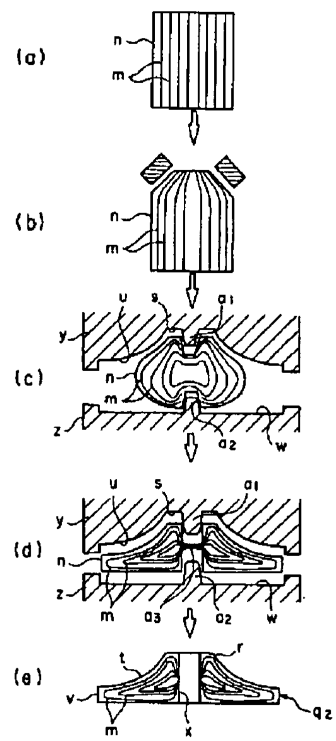
【図17】



【図18】



【図19】



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